REPORT

OF THE

COMMISSIONERS AND CHIEF ENGINEER

OF THE

CHARLESTOWN WATER WORKS.

FEBRUARY 28, 1865.

BOSTON:
LITTLE, BROWN AND COMPANY.
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REPORT

OF

WATER COMMISSIONERS.

WATER COMMISSIONERS' OFFICE,
CHARLESTOWN WATER WORKS, *February* 28, 1865.

TO THE CITY COUNCIL OF THE CITY OF CHARLESTOWN:

THE Water Commissioners respectfully present this their final report, and that of the Chief Engineer, upon the construction and condition of the works intrusted to their care.

The time having arrived, when, from the near completion of the aqueducts and works, all the rights, powers, and authority granted to this commission should cease, and be exercised by the City of Charlestown; the Board feel it a duty they owe to the government and citizens, that a report of their doings, and a description of the Water Works, should be presented. Believing that their importance demands it, and that the whole subject may be better understood, they have taken the liberty of making the same somewhat retrospective, and would refer briefly to the history of the works prior, as well as subsequent, to their appointment.

Although the need of a proper supply of water has been for very many years acknowledged, and the want of it at times

severely felt, it does not appear that any public action, tending to obtain such, was had until the passage of the legislative act authorizing the City of Boston to supply East Boston with Cochituate water. This act, passed in 1849, required that hydrants should be erected along the line of the aqueduct, in such streets as it passed through. The water therefrom could only be used in cases of fire, and for such purposes no charge was to be made. Although limited to the line of pipe, and in its use, yet the advantages arising from the nine fire-plugs thus obtained, have been duly shown, not alone in enabling us more readily to extinguish conflagrations, but at times admitting of obtaining a supply for our reservoirs, and more recently for some of our citizens most in need during a period of extreme drought. The partial benefits thus experienced led the authorities to endeavor to procure a like supply, when the right to lay pipes through another portion of the city was granted to the State Prison. The attempt was not successful, and the only benefit derived was limited to the establishment to which the right was given. As the want of a proper supply of water would have rendered necessary the removal of the institution to some other locality, it is doubtful if any gain was had to the city whatever.

April 13, 1854. Sundry gentlemen interested in the Cambridge Water Works procured from the Legislature the right to supply Charlestown with water, under the name of the Charlestown Water Works. No particular source was mentioned in this grant, and it was not until the following year that the incorporators instituted any important investigations, it being supposed that either Spot or Mystic Ponds would be made use of. The examinations made of the first-named source by Mr. Henry Hubbard, civil engineer, showed, that while no doubt existed as to the proper elevation, or the purity of the water of Spot Pond, yet, from the small quantity it would supply, and the heavy damages that would have to be paid to the mill-owners,

it was unadvisable to use this lake. It was mainly the latter reason that induced the Company to look to Mystic Pond as the proper source: the fee of this pond being (as was supposed) in the Commonwealth, while Spot Pond was owned by individuals, who, as long ago as 1837, asked for one half of the same, $65,000.

But little appears to have been done until May, 1857, when the right was obtained from the Legislature to contract with other companies. Under this authority the Company proceeded to make contracts, and had selected and staked out a site on Bunker Hill for a Reservoir, with a view of using the waters of Fresh Pond in Cambridge. The City of Cambridge becoming alarmed, obtained a perpetual injunction: having shown conclusively that this pond was scarcely adequate for Cambridge alone, whenever more than half the city was supplied by the Water Works.

In June, 1857, their engineer was instructed to make surveys and plans for a supply of water from Mystic Pond. As the Company at that time designed to supply Chelsea and East Boston, the plan proposed was to elevate the water to a reservoir on Powder-Horn Hill, in Chelsea, and from thence also supply Charlestown. This plan was submitted to the authorities of the various cities, and was favorably considered by the mayors of Charlestown and Chelsea. (*Vide* address Hon. James Dana, January, 1859, &c.)

In September, 1858, Mayor Dana, perceiving the importance of action on the part of the city, formally called the attention of the Council to the subject, and also again in his inaugural of January, 1859.

In February, of the same year, the Charlestown Water Works Company made application to the Legislature, to draw water from Mystic Pond. They having failed to give proper notice to the towns interested, their application was refused; and thus ended the first organized plan of a water supply.

It becoming evident, from the increasing requirements of the

city, that more energetic action was necessary, in August, 1859, the City Council authorized Mayor Dana to obtain a charter to supply the city with pure soft water. The services of Messrs. George R. Baldwin and C. L. Stevenson, civil engineers, were engaged, and detailed scientific examinations made by them of all the sources within fifteen miles of the city. None were at all favorable except Spot and Mystic Ponds. In their careful examination of Spot Pond, they only corroborated the statements of other scientific men, that it was inadequate for the wants of the city. This pond has, from its favorable elevation and position, and from the purity of its waters, undergone more searching examinations than any other source in this vicinity.

Professor Treadwell, in 1825, in a report to the city of Boston, estimated its yield as high as 1,600,000 gallons per day. Subsequent investigations by Loammi Baldwin, in 1835, did not quite sustain these estimates, though agreeing substantially with him.

In 1836, R. H. Eddy, civil engineer, proposed this pond as a source of supply for the city of Boston, the deficiency in its yield to be made up by pumping from Mystic Pond.

In 1836 and 1838, Messrs. Treadwell and Hale, Water Commissioners, accurately measured the flow, and found it for these years to be 1,700,000 gallons per day.

In 1839, Mr. James F. Baldwin, water commissioner and civil engineer, estimated the yield to be 1,480,893 gallons.

The pond was not again examined until 1845, when Mr. J. B. Jervis, the engineer of the Croton Water Works, and W. B. Johnson, civil engineer, were appointed commissioners for Boston. These gentlemen were the first to apply to the gauging the test of measuring the area of country draining into the pond, and the quantity of yearly rain-fall. As all the water the pond can furnish is a certain percentage of rain-fall on the drainage area, it is evident their deductions are conclusive. They found the yield to be 1,500,000 gallons per day, derived from a drainage area of 1,100 acres; the extreme elevation of this pond accounting for the small area of country that could drain into it.

In 1857, this pond was suggested as a source of supply for East Boston; but investigations by "city engineer" Slade, and the president of the Cochituate Water Board, showed that this single ward of the city was then, with 16,000 inhabitants, using more water than this pond could supply, — the great consumption in this ward being attributed to the large amount of machinery and manufacturing interests that had become there established, mainly from the facilities afforded by a copious supply of water.

In January, 1860, application was made to the Legislature "for the grant of such powers as might be necessary to enable the City of Charlestown, either by itself or in connection with the City of Chelsea, to obtain a supply of Pure Soft Water for the use of the inhabitants of said city or cities." This petition was referred to the committee on "Mercantile affairs, and Insurance," and encountered a most terrific opposition. The parties interested in Spot Pond, in the Rubber Works, in the Flour Mills, and the Barrett Dyeing Company, the land-owners around Mystic Pond, the city of Boston, the town of Medford, the Boston Board of Trade, merchants of Boston in behalf of Boston Harbor, and ship-owners and builders from Medford and East Boston: no less than six learned counsel appearing in the case. His Honor, Mayor Dana, and ex-Judge Abbott appearing for Charlestown. The Hon. Edward Everett also appeared in behalf of his own and the public interests.

After thirteen protracted hearings and personal examinations of the premises, the committee, with but one dissenting voice, reported that, —

"There was an existing necessity for pure water in Charlestown;

"That a source of supply was at hand;

"That water could be readily obtained from that source (Mystic Pond), in an economical manner;

"That it could be done without great injury to private rights;

"That the city of Charlestown was prepared to carry into effect the project proposed; and

"That the navigation of Mystic River and the harbor of Boston would not be injured by the plan, if carried into effect."

After a severe contest in the Legislature, the bill reported by the committee passed both houses by large majorities, but failed to receive the sanction of the executive (Gov. Banks), on the ground of possible damage to Boston Harbor; and the matter was then referred to the next General Court.

The necessity of a water supply daily becoming more evident, Mayor Dana was authorized to apply to the Legislature, at its extra session in June, for permission to obtain water from the Boston Works. The act was passed June 12, 1860; but all subsequent efforts to obtain other than a temporary supply from the hydrants failed, it being evident that the Cochituate works were barely ample (as since shown), for the supply of Boston alone.

The veto of Gov. Banks being based upon the possible or probable damage that might ensue to Boston Harbor if the proposed dam of the Water Works should be erected at Mystic Pond, it became essential that proper investigations on this head should be made; and in August, 1860, the City Council directed Mr. Stevenson "to test the effect on Boston Harbor of the ebb and flow of the tide in Mystic River; also the effect on the same likely to be produced by the building of a dam across the outlet of Mystic Pond." Similar investigations were directed to be made by the U. S. Harbor Commission; and, as the investigations were to the same end, the forces employed for the city and the commission were united.

The report to the city was made December 29, 1860; that of the commission in February, 1861. The conclusions arrived at by Mr. Stevenson, were, —

"*First:* That as a tidal basin, Mystic River is of the utmost importance to the preservation of the channels of Boston Harbor. That its value as such at present extends only to a point between Medford and Mystic Pond; and that said pond is not a tidal reservoir of present value to the harbor.

" *Second:* That the fresh-water flow from the Mystic Pond is not appreciable on the harbor; and that a large portion of its flow is detrimental to the river.

" *Third:* That the erection of a dam at the outlet of Mystic Pond, as proposed by the City of Charlestown, will not injuriously affect Boston Harbor or Mystic River, but on the contrary may be so constructed as to benefit both."

Some of the facts adduced are thus stated by the Harbor Commission: —

" That it is only during the dry season that Mystic Pond can be classed as a tidal reservoir; and that even then the presence of the tide-wave in the basin is scarcely appreciable.

" That, under ordinary circumstances, Wood's Mills may be regarded as the point at which the true tide ceases.

" That the outflow from Mystic Pond does not produce a measurable effect upon the times of the currents in Boston Harbor below Charlestown."

They recommended, however, that it was inexpedient to make the changes proposed by the City of Charlestown, as the Lower Pond *might be converted* into a tidal reservoir of value to the harbor.

In 1861, the matter was again brought before the Legislature by Mayor Hutchins; and, after a patient investigation of the new facts, this second committee were of opinion that no detriment to the harbor would ensue from the contemplated works. In view, however, of the stubbornness of the opposition, and the required removal of extensive erections made on the Lower Mystic during 1860, which would enhance the cost of the work, it was deemed expedient, by the City of Charlestown, to limit their operations to the occupancy of the Upper Mystic Pond; the rapidly increasing wants of the city rendering it also unadvisable to run the risk of another year's delay.

In March, 1861, the act under which the works have been constructed was passed. By it the city is authorized, —

"To take, hold, and convey by steam, or other power, to, into, and through the said city, by suitable aqueducts or pipes, the waters of Mystic Pond, so called, in the towns of Medford, West Cambridge, and Winchester, and the waters that may flow into and from the same, and may also take and hold, by purchase or otherwise, any land, real estate, or water rights necessary for erecting, laying, and maintaining, and may erect, lay, and maintain such aqueducts, pipes, dams, gates, pumps, bridges, reservoirs, embankments, water-ways, drains or other structures, as may be necessary or convenient to insure the purity of the waters of said Pond, or the ponds and streams running into it, or to convey said waters into, and for the use of the said City of Charlestown; etc.

The city is also authorized to supply Boston, Chelsea, and the towns through which the line of aqueduct may pass. It is limited to the use of the waters of the northerly division of Mystic Pond, and can raise the waters of said division seven feet above the original level thereof.

September 10, 1861, the act was accepted by the citizens, by a vote of 944 in the affirmative to 251 in the negative.

November 15, 1861, an ordinance to regulate the proceedings of the commissioners was passed, and,

December 10, 1861, Edward Lawrence, Matthew Rice, and Geo. H. Jacobs were appointed commissioners conformably to the act of the Legislature. These commissioners organized Jan. 8, 1862, and, on April 5th, appointed C. L. Stevenson chief engineer, and George R. Baldwin, consulting engineer.

September 27, 1862, work was commenced, with appropriate ceremonies, on Walnut Hill Reservoir.

February, 1863, an additional act was obtained, authorizing the temporary lowering of Mystic Pond outlet, to facilitate construction.

November 29, 1864, the water was formally introduced into the city with imposing ceremonies.

In entering upon the duties confided to them, the Board at the outset felt the great responsibility of undertaking a work of its size and cost, at a time when the greatest civil war the world has ever seen was in progress in our country, and the demands upon the city treasury for sustaining the honor of the nation were daily increasing. Could they have foreseen events, it would have certainly required more courage than is ordinarily possessed, to have undertaken the arduous duties of the past three years.

The vast importance of this great enterprise, its inestimable value to our city as conducive to the health and comfort of our citizens, and the great advantages that will accrue from the facilities thus afforded to the mechanical, manufacturing, and general business interests of the city, are now so manifest, as to demonstrate that they have but anticipated an *actual necessity*, and that a postponement for a longer period would not only have prevented the large increase of manufacturing establishments, our abundant favorable localities warrant us in anticipating, but hazarded even the continuance of those now in existence.

The line upon which the present work has been built was adopted May 24, 1862, after a careful examination of the routes that seemed at all feasible, and, during the season of 1862, contracts were made for nearly every portion of the works.

The commissioners, having in view the experience of other cities and towns, in which, for want of sufficient capacity and thoroughness of the work, large outlays had been made necessary both for extensions and repairs, determined at an early period that so far as possible the Charlestown Works should be constructed of a capacity most ample, and in a style of workmanship substantial and thorough. They therefore determined to increase the capacity of the works over that originally proposed by Messrs. Baldwin and Stevenson, in 1859, so as to provide for contingencies not far remote, when our adjacent cities will require a supply

from the Mystic Lake source; and the applications for the same from two of our largest neighbors so soon after the introduction of the water, is a pleasing proof of the wisdom of the course adopted.

Prior to awarding the contracts, the commissioners visited the principal pumping-works in the country, the works of the Warren Foundery, and New Jersey Water and Gas Pipe Company, with which corporations two of the most important contracts were subsequently made.

Among the most important and difficult decisions to be made, was as to the kind of pumping machinery that should be adopted. Nearly every style of engine in favorable operation was visited, and each type had its advocates. With so many forms to select from, each possessing marked points of advantage, it may be well to consider the peculiarities of the engine finally adopted by the Board, and to state the reasons which led to the choice. In every engine whose working they inspected (except the one at Harrisburg, Pa.), a severe concussion at every stroke was noticed, which could not but produce results more or less destructive. In a word, they appeared exposed to constant danger, and to be unreliable. The parts were enormously large and heavy, and likely to produce great mischief by their momentum in case of accidental derangement. Their foundations were very expensive, often amounting to as much as the cost of the engine, and the engine-houses were also of an expensive character. These objectionable characteristics appeared to be obviated in the engine finally selected, a more detailed description of which will be found in the engineer's report. Its remarkable and almost distinctive advantage is the entire absence of all noise or concussion. The water flows through the forcing main so equably as hardly to disturb the most delicate pressure-gauge, and passes into the reservoir in a perfectly even and unbroken stream. There is also no jar or irregularity of movement; the amount of metal in motion is small, and there are no oblique strains in any part of the machine.

The engines were contracted for under an unqualified guaranty

as to performance and workmanship. They were to equal any engine heretofore erected in this country, on both these points, and no money demanded until the guaranty should be fulfilled. The engine now in use, having performed this guaranty, has been accepted.

Considerable progress was made during the autumn of 1862, by Mr. James McDonald, the contractor for the dam, conduit, reservoir and iron pipe laying, — the work being continued as long as the season would permit.

Between the suspension of the work in 1862, and its commencement in the spring of 1863, the prices of labor and materials necessary for the fulfilment of these contracts had increased so much, that the contract prices (based as we believe upon an intelligent knowledge of the cost and a fair remunerative price for the services) were found inadequate for a satisfactory progress; and in order to cause a more vigorous prosecution of the works, it was deemed advisable to advance the prices, and, finally, to relieve the contractor from the responsibility of the labor portion, at the same time securing his energetic and well-directed services in the management of the work until near the close of the season.

It is proper here to state, however, that the increase of cost over the original estimate made by the commissioners is not to be attributed alone to the causes alluded to, but is in a great measure due to the enlargement of the works as before stated.

The New Jersey Water and Gas Pipe Company early commenced operations, and, having opportunities of supplying all the materials required by them, they were enabled to prosecute their work without any advance until 1864, when some modifications were made.

The construction of the engine-house was commenced early in 1863, by our well-known townsmen, Messrs. W. W. Bray and John B. Wilson, and was successfully completed by them during the season of 1864.

In this connection the commissioners beg leave to state their entire concurrence in the views expressed by the chief engineer

as to the faithful workmanship under the several contracts, and their approval of the manner in which the various mechanical and labor departments have been directed and the work executed.

In order that our citizens might be supplied with water immediately upon its introduction, the commissioners were authorized and directed to make the necessary arrangements for this purpose, and applications have been received since March, 1864. Bills for the water-rates have already been made and collected, amounting to $8,123.12, which has been deposited in the city treasury. It is gratifying to know that in this the third month of its introduction the water is already *supplied* to 990 families, 52 stores and shops, 17 manufacturing establishments, 43 stables, 10 saloons, 4 engine-houses, 1 church, 1 armory, and the McLean Asylum at Somerville. There are further applications for water from 418 families, 25 shops and stores, 8 manufactories, 18 stables, and 2 saloons. The laying of the house services to the line of the street at the expense of the city has doubtless been the means of inducing many to take the water, who would otherwise (from the high price of materials) have been deterred from so doing.

In the settlement of land damages, the commissioners have endeavored to arrange with the parties upon equitable and amicable terms, in order to save the vexation, delay, and expense of litigation in courts, and have been enabled thus to settle a large majority of the cases upon terms which they deem to have been for the interests of the city, and just to the parties. In the five or six cases remaining to be adjusted, the claims of the parties were so exorbitant, that the commissioners thought it best to allow them to be settled by the courts, relying upon an intelligent jury to make a just award. It is likewise believed that time will, as in several instances on the Boston works, demonstrate to the parties themselves that much less damage will ensue to them than they are now disposed to believe.

The expenditures for construction, exclusive of interest, as will

be seen by the detailed statement, are $731,575.83. The estimated cost, as the works are now designed, will be about $800,000, which will be increased, should the land damages exceed the estimated amounts, and by the extension of pipes and services. The supply to other cities will of necessity entail an outlay for such extensions; but the revenue to be derived therefrom, it is believed, will tend to reduce the debt created.

Large as has been the cost, the commissioners cannot but feel that the benefits to accrue to the city will more than justify the outlay. It will admit of the occupancy of some 300 acres of land within our limits, which, without water, would remain vacant; lands that, from their location, are, for manufacturing purposes, every way desirable, since they are in many instances nearer the business centres of Boston than many parts of that city itself, and are contiguous to railroads and the deep waters of the harbor. But the many other benefits to both public and private interests, as afforded in the increased security against fires, and the consequent saving in insurance and expenses of the fire department, — in the increased value given to property, and the individual comfort and sanitary improvements which it entails, — are too important to be overlooked or forgotten.

The thanks of the Board are due to C. L. Stevenson, Esq., chief engineer, for the skilful and energetic manner in which he has planned and executed the work.

The selection of Geo. R. Baldwin, Esq., as consulting engineer, is believed to have been a fortunate one, as his large experience in works of this nature has rendered his advice valuable to the commissioners, and serviceable to the city. His approval has been given to the plans and execution of the works.

The Board also take pleasure in acknowledging the intelligent manner in which the efficient clerk of the Board, W. W. Peirce, Esq., has performed the varied and arduous duties pertaining not only to his office as Clerk, but also to those of Paymaster, Water-Registrar and Collector.

In conclusion the Commissioners would state that all books, papers, and properties of every description, are in readiness to be delivered to their successors.

Respectfully submitted.

EDWARD LAWRENCE, *Chairman.*
PHILANDER S. BRIGGS.
MARSHALL N. CUTTER.

COST OF WORKS TO FEBRUARY 28, 1865.

Dr.

CONSTRUCTION.

Salaries	$17,644.61	
Engineering, including salaries of chief and consulting engineers	29,013.06	
Land damages	29,502.61	
Reservoir, including gate-houses and chambers	115,759.50	
Dam	15,291.36	
Conduit, including gate-house and appurtenances	128,833.29	
Engine, boiler-house and chimney	24,054.81	
Engine and appendages	34,330.14	
Grubbing around pond	7,850.77	
Iron pipes and special castings	106,173.79	
Laying iron pipes, feed, force, and supply mains	60,287.60	
Pipes for city distribution, including setting hydrants and stop-gates	79,396.41	
Hydrants	11,173.37	
Stop-cocks	12,140.92	
Contingencies	8,282.57	
Roadways and bridges	2,956.98	
Lowering Mystic River	2,821.11	
Inspectors	1,824.79	
Service pipes, including stop-cocks	36,514.02	
Somerville distribution	11,126.20	
Hydrants for Somerville and Medford	1,353.08	
		$736,330.99

Cr.

LAND DAMAGES.		
By amount received for wood, &c.	$330.91	
IRON PIPE.		
By am't rec'd from Gas Co., for crossing R. R. Bridge	300.00	
CONTINGENCIES.		
By amount received from sale of tools	84.25	
SOMERVILLE DISTRIBUTION.		
By am't rec'd for laying pipes to McLean Asylum	4,100.00	
		4,815.16
		$731,515.83
Interest ac't to Jan. 1st, less interest rec'd and prems.		12,072.78
Cost of maintenance since introduction of water: —		
Pumping service	$3,185.83	
Contingent expenses	191.00	
		3,376.83
		$746,965.44

REPORT OF THE CHIEF ENGINEER.

Engineer's Office, Charlestown Water Works,
February 28, 1865.

Edward Lawrence, Esq.,
Chairman Water Commissioners, C. W. W.

Sir: I herewith respectfully submit a report descriptive and giving briefly the history and condition of the Water Works as constructed under your direction. While the details of the works, as built, are familiar to those who have been engaged therein, it is important that a proper record should be made, describing the whole as *actually completed*, for the information of the City Government, and of subsequent boards of control. Experience upon other works has demonstrated the necessity of full and careful descriptions, since, after the lapse of time and those engaged upon the construction have departed, it has been difficult, or impossible, to obtain proper information without great trouble and expense. Hence the report is of necessity long, though condensed as much as is deemed consistent with reference to the giving of proper details.

Under your direction, in 1862, surveys were commenced to ascertain the best and most feasible routes for, and methods of, constructing the works authorized by the act of the Legislature. Four different routes were examined and reported upon. Two of these contemplated reservoirs on Wyman's Hill in West Cam-

bridge; the others were modifications of the present adopted route.

In July, proposals for the construction of the various portions of the work were issued; and, after a visit of inspection to Water Works in other cities, contracts were made for building the principal portions, and the work was begun on the 27th of September, 1862.

MYSTIC LAKE.

The source of supply, the northerly or upper portion of Mystic Lake, is situated in the towns of Medford, West Cambridge, and Winchester, $6\frac{3}{5}$ miles from Charlestown Square. It has an area of about 200 acres when flowed to the level authorized by the act, and a storage capacity at that level of 380,000,000 gallons of water. The area of country forming the drainage basin is thirty-one square miles, exclusive of the areas of the water surfaces of the ponds and streams lying within the basin. The principal ponds are Horn, Wedge, and Winter, and the waters flowing from these and from streams rising in Reading, Wilmington, and Woburn, all flow into the lake. These numerous ponds serve to collect and retain the water derived from the rainfall, checking at various points the rapid flow which would otherwise take place to the Mystic River.

Frequent gaugings during the past six years have enabled us to obtain with considerable accuracy the quantity of water the lake will furnish. These results are happily verified by estimates upon the available rainfall upon the drainage basin. This basin is, throughout the greater part of its length and breadth, a deposit of gravel and sand of considerable depth, underlaid with primitive trap, of the common greenstone variety, which crops out on the tops and sides of the higher hills lying in and around the basin. The rainfall upon this gravelly, sandy soil is rapidly absorbed and held comparatively free from loss by evaporation, while the water collects and is conveyed in an equable and gradual manner to the watercourses which supply the pond. A district of this

nature is, therefore, one favorable to a high ratio of drainage. It will be seen, by examining the accompanying plans, that the pond lies at the extreme southerly edge of the drainage basin, and that the water, as it is collected, is daily delivered to it in a manner which serves to keep the supply comparatively regular; the numerous ponds above, being under control, serve as so many storage reservoirs, from which a daily quantity is delivered. We are therefore led to believe that for the greater part of the year the supply would be large in comparison with the amount of water usually obtainable from a given area of drainage; though in the spring, when the surface of the ground is frozen, a large quantity of water is unavoidably lost in the freshets.

From all the data collected, it is deemed safe to estimate the daily yield of the lake at 30,000,000 United States gallons. As no tables of rainfall have been kept within the basin, we have been obliged to use those of Boston and Cambridge, and which it is believed are sufficiently near for the purpose. The Mystic basin is quite as favorable for a high ratio of drainage as that of Lake Cochituate, which it closely resembles; and from this last, with a water-shed of 17.8 square miles, the average daily yield for ten years has been 23,700,000 gallons. With the same percentage of rainfall Mystic Lake basin should furnish upward of 41,000,000. The least amount ever obtained by the gaugings was 11,900,000 in twelve hours. Should it ever be deemed advisable to store some of the surplus water so as to obtain more than 30,000,000 gallons per day, Horn Pond and the Lower Mystic could with legislative authority be made to hold a reserve of 500,000,000; while the yield of the Lower Mystic would be in addition about 3,000,000 gallons per day. As regards a still further quantity of water, some remarks will be found under the head of "Supply of water to other cities."

The territory of Charlestown is capable of containing, when filled to its present limits, a population of 75,000 persons, which under ordinary regulations will require nearly 5,000,000 gallons of water per day. Of a sufficiency of supply for Charlestown

alone, unless its territorial limits are extended, there certainly can be no question.

The water of Mystic Lake is celebrated for its purity, its potable qualities being already favorably known to our citizens; and in this last respect it is admitted as excelling either the Cochituate or Fresh Pond waters. The corroborative testimony of Professors Silliman and Horsford, Drs. Jackson and Hayes, as shown in their reports, should thoroughly set at rest any doubts ever entertained as to its entire fitness. To thoroughly conserve its purity, the flowage of six or seven feet in height was deemed advisable, as it admitted of a sufficient depth, over the shallow portions of the lake, to completely drown out those vegetable growths that at certain seasons are liable to unpleasantly affect the taste and smell of the water. Further to avoid if possible those difficulties experienced upon other works, of impure water, caused by the gradual dying out of the submerged trees and shrubs, the shores of the lake and all those portions reached by the flow were completely grubbed, and all roots, shrubs, and plants removed. Wherever deemed necessary a slope walling or riprap has been placed on those portions of the shore subject to wave wash.

The rising of the water rendered necessary the covering of some eighty acres of swamp and meadow lands, and the flowing out of the mill-privilege commonly known as "Bacon's," occupied by the Fibrilla Felting Company. A small water-privilege used for wool-washing by Mr. Bacon, was also destroyed. The raising of the lake likewise necessitated the removal of some small buildings, and the raising of Mr. Bacon's steam-mill. The lands flowed are comparatively of small value, and it is rare that so considerable an area is flowed, in a well-populated region with so little damage; but, with the exception of the instances just mentioned, the riparian proprietors are, as predicted by a celebrated expert, actual gainers by the change of water-level, by the improvement of the landscape "in the element of beauty, if not of land."

To convey the waters of Mystic Lake to our citizens the works consist of

Dam and Overfall;	Reservoir with Influent, Effluent and Drain Chambers, Gate-House and Appurtenances;
Conduit with its appurtenant Gate-Houses, Waste-Weir, Ventilator, and Drains;	Supply Main from Reservoir, with Gates, Air-Cocks, Blow-Offs, and Connections;
Cast-Iron Mains under Mystic River, Bridge, &c.;	City Distributions, Hydrants, Gates, &c.;
Engine-House and Pump-Well;	Service-Pipes, Stop-Cocks, Meters, Fountains, etc.
Pumping Engines;	
Force Main with Check-Valves, Gates, Hydrants, and Blow-Offs;	

DAM AND OVERFALL.

The act of the Legislature, restricting the city to the use of the upper or northerly portion of Mystic Lake, required that the Dam should be constructed at the narrows or parting (so called), a narrow strait between the shore projections, giving to the pond the shape of a figure eight. These portions were nearly of equal area, and the strait varied in width from fifty to two hundred feet, according to the height of the water. Across this strait and along the low shores, until the proper elevation was reached, a dam, 1,560 feet long has been constructed. It is substantially built of earthwork and masonry, and although constructed through a difficult quicksand formation, presenting unusual difficulties, it was successfully completed by the contractor. The height of the Dam is 11 feet above high-water mark of Boston harbor, and the original level of the lake, or 4 feet above the authorized limit of flowage. It is 15 feet wide on top, and mainly constructed of the sand and gravel excavated from the conduit line. The side slopes are two to one, and where subject to wash are riprapped with stone. Two rows of six-inch sheet piling, 15 feet long, and driven to an average depth of 11 feet below the water line, extend across the main portion of the Dam for a distance of 550 feet. Between these rows, which are 4½ feet apart, a puddle wall, composed of carefully prepared materials from the banks of the Middlesex Canal, is built, and against the interior of the lower

side, as an additional protection against infiltration or percolation, a wall of concrete masonry, of an average thickness of 18 inches, is laid. A single row of sheet piles, 6 inches thick, extends a further distance of 330 feet, protected on the upper side with concrete and puddle walls.

The overfall of the dam is constructed of cut granite (rock-face) masonry, and consists of five piers and two abutments, with six waste openings of six feet each. The distance between abutments is 80 feet, the piers being 5 feet wide at base and 11 feet long in the direction of the stream. The whole structure rests on piles driven into the quicksand 18 feet, with a covering of 18 inches of concrete, and an apron or base course of 18 inches of cut granite. The lines of 6 inch sheet piling extend on both sides of the base of the overfall and the concrete masonry covering the piling extends out thereto. A neat and substantial wooden bridge reaches from one abutment to the other, and is fitted with movable traps to admit of readily adjusting the overfall planking. Of this overfall planking there are two rows, 6 inches thick, fitted to grooves in the masonry, and susceptible of removal to regulate the height of the water in the lake. The intermediate space between the planking is puddled to prevent leakage.

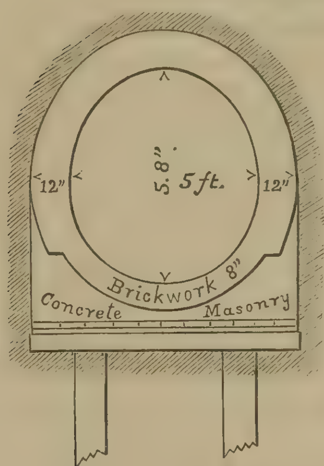
The dam was commenced in October, 1862, and has been a work of more than usual difficulty, and reflects credit upon the builder for its substantial character and neat construction. The most careful examinations have failed to detect *any leak*, and it is believed to be a work capable for all time of performing (with ordinary care) its allotted part in our works.

CONDUIT AND APPURTENANCES.

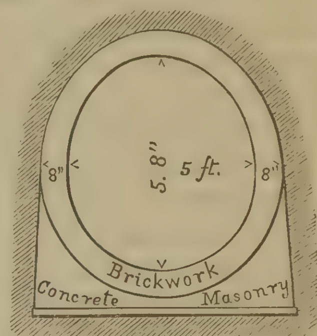
The Conduit extends from the lake to the pipe-chamber on the north bank of Mystic River, and conveys the water to the iron pipes passing under the bed of the same, a distance of 7,453 feet. It is constructed of hydraulic brick masonry, 8 inches thick, excepting between the upper gate-house and the waste wier, where all above the springing line of the arch is 12 inches thick, — the bet-

ter to protect it in case of pressure being brought upon the masonry, and to which this section is liable. In shape it is oviform 5 feet 8 inches in height, and 5 feet wide, interior dimensions, the base being semicircular 5 feet diameter, the upper segment having a rise of 3 feet 2 inches. To better protect the work, the whole structure is laid in a foundation of concrete masonry, varying in dimensions as the nature of the bottom demanded, and rising upon the sides to nearly the spring line of the arch. The general form of the exterior will be better understood from the annexed diagrams, than from any description that can be given.

SECTIONS OF CONDUIT.



SECTION NEAR GATE-HOUSE.



GENERAL SECTION.

The whole exterior of the brickwork is coated with hydraulic cement mortar, the more thoroughly to insure against percolation or undesired leakage from without. The level of the inside of the invert of the conduit at the lake is 4 feet 2 inches below tide water, and 11 feet 2 inches below the line of authorized flowage. The total fall to the pipe-chamber is nine inches, the general inclination being six inches to the mile. With this grade the conduit will convey when running, as it is designed to do, within 8 inches of the inside of the

crown of the arch, 35,000,000 gallons in twenty-four hours, supposing a free delivery into the pipe-chamber. This quantity is calculated from the accepted formulas for water-flow, but from some experiments made, I am led to infer that the capacity, as in the case of the Cochituate conduit, is an excess of the calculations. The first three thousand feet of the conduit, known as the "pond section," was a work rendered necessary by legislative requirement, and was attended with probably greater difficulties than any work of its size in this country. It passes around and along the easterly side of the lower Mystic, a shore line of steep side-hills with abrupt bends and many sudden changes of direction. To procure an alignement with admissible curves, it was necessary to carry the work through heavy cuttings, across deep bays, upon pile foundations; and when it is remembered that the bottom of the excavations for foundations was from five to six feet below the water-line of the pond, requiring constant and costly pumping, some idea of the obstacles overcome can be had. The soil along the whole route was extremely porous, being generally a coarse, loose gravel, through which the water flowed with great volume, — so great that at times it was necessary to elevate with the pumps one million gallons in three hours. Anticipating some of the difficulty that was had from water, the required authority of the Legislature was obtained, during the winter of 1863, to construct at the outlet of the lower Mystic a system of tidal gates, whereby the average level of the lake could be reduced. The construction of these gates enabled us successfully to lower the lake some two feet. Without the assistance thus afforded, it would not have been possible, without greatly augmented pumping power, to have effected the work at all. It is gratifying to be able to state, that upon this most difficult section there are but very few leaks discovered, and these of a trifling nature. Upon the lower section near the Mystic River, and in the locality of numerous land springs, it was found that three leaks could not be stopped without endangering the stability of the work. They were accordingly opened and the springs admitted into the conduit. They have

thus far continued to run unceasingly, and with considerable volume, and as the water is of unusual good quality, they are rather a valuable acquisition than a detriment.

The earthwork of the conduit was begun in October, 1862, though nearly all of the important work was performed during the summer and fall months of 1863 and 1864. The greater part was performed under a contract with Mr. McDonald, and under the immediate inspection of Mr. Albert Whiting, Superintendent of Masonry. To the care, skill, and fidelity of this gentleman, the thanks of all interested are due for the successful performance of a most difficult work.

The principal appurtenances of the Conduit are known as the Gate-Chamber, Waste-Weir, Ventilator, and Pipe-Chamber.

THE GATE-CHAMBER

Is situated near the easterly extremity of the dam, and is carried out into the lake, so that the water is taken where it is of ample depth to avoid shore impurities. It is constructed of cut granite masonry externally and lined with brick-work, the whole being laid in hydraulic cement. The foundation, like that of the dam, was laid upon quicksand, but owing to the greater depth of water it was necessary to build a substantial coffer dam within which the work was constructed. This dam, with the exception of a water-way to the gate openings, was left in the work as adding to its stability and that of the surrounding banks. Into the quicksand oak piles were driven, upon which was placed the concrete masonry to receive the flooring of cut granite. The gate-chamber is divided into a receiving and two screen chambers, which last unite at the conduit head. The water from the lake passes into the receiving-chamber through two openings in the masonry four feet square, which are protected by vertical cast-iron gratings. On the exterior of the front a heavy white oak framework is bolted. and fitted with grooves, so that stop-plank can be placed outside of the openings, and the water excluded from the building ; a very

necessary protection, as, in case of accident to the inside gates or receiving-chamber, they become readily accessible for repairs. The passage of the water from the receiving-chamber to the screens and conduit is regulated by two gates three by four feet. These gates are fitted with composition bearings throughout, and regulated by a screw passing through a nut of the same material. The screens are of fine copper mesh, and fitted with reference to ready removal for cleansing. A neat and substantial gate-house of face brick is erected over the chamber, so as to protect the gates from being interfered with by unauthorized persons.

WASTE-WEIR.

The Waste-Weir is a structure designed to carry off the surplus water into the lower lake, and that its level in the conduit may be so regulated as never to bring pressure upon the masonry southerly of the weir. Owing to the very low level and the little difference between the water within and without the conduit, the waste-weir has been constructed of unusually ample dimensions, the over-falls being five in number, and each six feet long. The chamber is like the gate-chamber, constructed of brick and cut granite masonry. The flow over the weir is regulated by stop-gates, upon which, to prevent the passage of fish, copper wire screens are placed. It is believed that this provision, with those at the head-house, will effectually prevent a recurrence of the recent difficulties caused by eels passing into the conduit.

VENTILATOR.

There is but one ventilator constructed as such, as the gate-houses, waste-weir, &c., serve the same purpose of permitting a free circulation of air through the conduit at all times. The importance of such a circulation is only too well shown in the improvement to the water by the aeration thus afforded. The ventilator is of brick masonry, in plan being a six-pointed star with an equivalent diameter of six feet, and is ten feet high, the roof being arranged to overhang, and the opening to the conduit protected,

so that mischievous persons cannot readily introduce anything to fill up the conduit or injure the quality of the water.

To admit of access to the conduit, man-holes are placed therein every fifteen hundred feet. These are curbed with granite with iron covers, and placed so that a covering of two and one half feet of earth is over them; experience having shown that any device of locks is no protection against interference by boys and others, and that the only means of preventing the work being interfered with, is to place the points of access out of sight, having them so located that the proper custodians can at all times readily find them. The utility of these man-holes has been already shown, and I can only regret that they were not placed more frequently.

PIPE-CHAMBER.

The Pipe-Chamber, on the northerly bank of the Mystic River, receives the water from the conduit and it is from thence delivered to the iron mains under the river. It is constructed of hydraulic brick masonry, and is interiorly divided into three portions, namely, one receiving and two delivery chambers. The water from the conduit passes into the delivery-chamber, which is fitted with two gates, of the same size and construction as those at the head gate-house, which regulates the flow into the iron pipes. This chamber is also fitted with a drain, to admit of emptying the conduit into the Mystic River. The drain is fitted with double gates three feet square, facing in opposite directions, the outer being intended to prevent any inflow of salt water during high tides, which sometimes rise above the level of the water in the conduit. The inside of arch at the entrance of the conduit to the chamber is nine inches above mean high water, and the spring tides rise at times one foot and three inches above this level; the highest known storm tide rising three feet and three inches above it. The level intended and recommended was that of spring tides. The two delivery-chambers, as an additional protection against eels or other fish finding their way to the pump-well, are fitted with copper screens, so that should by any possible accident fish find their way into the conduit, they

cannot pass beyond the pipe-chamber. These screens are in double sets, so that one can be removed for cleaning without disturbing the other.

The foundation of the pipe-chamber was, like some portions of the conduit, in a bad quicksand formation, and the bottom to receive the masonry was only obtained by sinking, one at a time, small wooden caissons, which could be rapidly emptied of the sand and as quickly filled with concrete. In this manner a stable foundation was at last obtained, and, although a slight settlement was observed in one corner shortly after completion, it is now believed to be in good condition, recent examination showing no change. A neat gate-house of brick is constructed over the chamber. At the pipe-chamber all that portion of the works intended to serve the water by gravitation as a canal or without pressure ceases.

CAST-IRON MAINS UNDER MYSTIC RIVER.

To convey the water from the pipe-chamber to the engine-house pump-well two iron mains 487 feet long and three feet inside diameter are used, and to meet the requirements of the act, these pass under the bed of the Mystic. To admit of their thus being laid, required that they should be placed 11 feet below mean high tide, and although a continuation of the gravitation portion of the works, they thus necessarily come under pressure. These pipes were placed in position by means of a coffer dam, occupying one half of the river at a time, and are laid and thoroughly incased in concrete masonry. One of these pipes will, with the difference of head between it and the conduit, deliver more than that will supply; yet to provide against accident two are provided. Every precaution has been used in this construction to guard against damage by settlement, and where the pipes pass into and through the engine-house, brick arches are erected over them to prevent any weight of either building or engines from affecting them. These mains are protected from immediate corrosive action, as are all the iron pipes used in the works, by being immersed, when heated to 300° F., in a bath of coal-tar pitch, distilled until the naphtha was

removed, and the material deodorized. The pipe and coal tar were of the same temperature, the heating of the iron so opening the molecules that the tar was more or less absorbed and retained by the exterior particles of iron.

To connect the two portions of the work divided by the Mystic River, a pile bridge is erected across the same, and directly over the iron mains. It is a substantial structure, and serves as an effectual protection to the mains from any injury by boats. Where the mains enter the pump-well at the engine-house, the gravitation portion of the work ends, and that of pumping begins. Down to this point the capacity of the work is 35,000,000 gallons in twenty-four hours.

ENGINE-HOUSE, PUMP-WELL, &c.

The Engine-House is situated on the southerly bank and about 200 feet from the Mystic River, being some 600 feet south-easterly from the junction of the Alwive stream with the Mystic. This stream is the outlet of Fresh, Spy, and Little Ponds, and the watercourses of the whole basin here unite on their way to the ocean. It is pleasantly located on the northerly slope of Walnut Hill, in Somerville, and surrounded by ample grounds, having a frontage on the river. It embraces, under one roof, the pump-well, boiler and engine-rooms, and repair-shop, and is a neat and substantial edifice, constructed of face brick and freestone 88 feet long by 57 wide. It is designed at present to accommodate two sets of engines and boilers, and with reference to future extension when the wants of the city shall require an increase of pumping power. The boiler-room is on a level four feet below the engine floor, and over it is the repair-shop, store-room, &c. The engine-room is neatly fitted up with linings of dark-colored chestnut, with heavy doors of black walnut, and when carpeted as designed, on the completion of the second engine, will be one of the most complete and convenient of its kind in the country. The chimney, an ornamental buttressed stack, is located on the southerly side, opposite the middle of the building, and 16 feet therefrom. It is of brick masonry, 105 feet high, starting from a granite base

15 feet square, with walls three feet thick, and commencing at a point five feet below the ground level. It consists of two shafts, the inner or smoke shaft being entirely separate and distinct from the outer, to prevent the effects of expansion from the heat from the boilers, with which it is connected by a flue passing in front thereof and under the boiler-room floor. The smoke-flue is 3½ feet in diameter, sub-drained to prevent condensation, and is carried up 80 feet. The mouldings and top projections are covered with copper.

PUMP-WELL.

The Pump-Well is located on the southerly side and under the engine-room. It is 30 feet long, 11 feet wide, and 14 feet deep. Its capacity, when at the usual pumping level, is 26,000 gallons. The well is sunk down to and into the ledge, which is covered with concrete to prevent leakage through seams and fissures, and upon this a layer of hard-burned paving bricks is laid edgewise. A small sub-well is sunk to a still greater depth, to admit of completely drying the well, for which purpose the feed-engine has been fitted with the required extra suction, strainers, &c. The side walls are of rubble masonry lined with hydraulic brick masonry three feet thick at bottom, and two feet at top. A favorable opportunity has recently occurred for a thorough examination of this work, when it was found to be in good condition, without any leak, and in every respect giving promise of properly performing its allotted part in the system of works. The drainage of surface water is not as complete as is desirable ; from the interior of the building however, the drains answer in every respect the purposes for which they were designed. The engine-house was completed under a contract with Messrs. W. W. Bray and John B. Wilson, whose skill in such matters is well known, and will I trust long remain to bear testimony to the fidelity of the execution.

PUMPING ENGINES.

These portions of the Water Works may perhaps be deemed the most important; for no matter how admirably all our other

parts may be adjusted, devised, or constructed, they are of no avail if this portion of the work should cease to operate. The engines adopted, and one of which is now in daily operation, are known as the "Worthington Duplex Pumping Engines," constructed by their inventor, H. R. Worthington, of New York. They are direct-acting horizontal engines, arranged in pairs, the valves of one being operated by motion from the other, so regulated that before one engine has ceased its stroke that of the other has begun. The steam is used expansively, passing from the high into a low-pressure cylinder and expanding through the stroke, the steam piston-rod connecting directly with the pump cylinders. The principal dimensions &c., are,

Low Pressure Cylinders	$43\frac{3}{10}$ inches.
High " "	25 "
Pump "	22 "
Total length of stroke	48 "

When pumping, the maximum required quantity the

No. of strokes per minute is	44
Steam pressure	45 lbs.
Vacuum	26 inches.

The boilers are cylindrical, multitubular, the

Diameter	5 feet, 3 inches,
Length	16 "
Size of tubes	3 inches.
No. " "	80

The water is discharged from the pumps to a delivery-chamber at the end of the force-main, and passes, owing to the arrangement of continuous motion, in a constant stream, without any concussion or slamming of valves.

This type of engine and pump combined was recommended after a personal examination of the principal pumping engines in

use in this country, as one that would, it was believed, *insure the best average annual performance of "duty," interest on cost and depreciation being considered, and was of such simplicity of construction as would admit of ease and safety in management.*

Engines of this kind, but of comparatively small size had been constructed for some other works, but none of them on a scale at all approaching to our requirements. The evidence afforded in the case of the Cambridge engine was the only reliable data that could be obtained, but this was extremely favorable. That engine was quite small, and it was the prevalent opinion that its admirable performance of "duty"* could not be obtained upon a larger scale on the same principle of construction. Mr. Worthington was of the opinion that duty could be excelled, and entered into a contract, guaranteeing to equal the performance of any engine in this country. His agreement being to construct two Duplex Pumping Engines, each capable of elevating in 24 hours 5,000,000 gallons of water (U. S. standard) 147 feet high, and delivering into the Walnut Hill Reservoir through a 30-inch pipe 3,300 feet long. I am gratified to be able to state, at this early day, and before the engines have been completely fitted as intended, that this guarantee has been fulfilled, as will be seen by reference to the tables of performance of other engines, and of that of the

* The term "duty" is applied to mean the actual weight of water raised by a given amount of fuel. Suppose an engine to raise 400,000 lbs. of water 100 feet high with 100 lbs. of coal. This would of course equal the raising 100 times as much one foot high, or 40 millions, and that will be the "duty." Up to the present time the peculiar form of pumping engine known as the "Cornish" has constantly maintained its superiority, and were it as applicable to the service of supplying towns as it is to deep mining, the question of the best form of pumping engine would scarcely have been raised. Being however intermittent in its action, a stand-pipe becomes necessary to avert the evils incurred in constantly starting and stopping the long column of water in the forcing main. It is also liable to dangerous irregularities of motion, and to concussions which constantly threaten the safety of the engine, and requires the most anxious and constant attention on the part of the engineer.

With these and other defects it still stands in great favor with many eminent authorities, and always shows a high rate of duty. The crank engine, under various modifications, has been its chief competitor, but as yet, so far as exhibited in this country, without reaching its economic excellence.

Worthington in January and February, 1865. The difference in coal consumption, as shown in the February working, is due to the more complete covering of the steam cylinders and pipes, and some modifications of the fire surfaces of the boiler.

The construction of the Worthington engine is such as not to require massive and expensive foundations; being extremely compact and working horizontally, they require but little more than sufficient to support their weight; and the entire cost of our engine and pumps will not equal that required for the foundations of the Jersey City Works for engines and pumps of a less capacity. The appurtenances of the engine, boilers, feed-pumps, hot-well, pipe-work, &c., are all of a character that reflect great credit upon the builders, being of a high order of workmanship and of ample capacity.

FORCE-MAIN.

From the engine to the influent-chamber the water is conveyed through an iron main 30 inches in diameter, and 3,277 feet in length. This main, for a distance of 2,100 feet, is laid with solid lead joints, caulked inside and out, and is connected with the force-pipe of the second engine by means of a Y, so that either or both engines can use the same main. The main starts at the engine, at a level of 16.5 feet above tide water, and the grade is a gradual rise from the same to the reservoir. Near the engine-house the two pipes before, and at the connection, pass in embankment. They are laid on solid rubble masonry, with flanged joints, and are fitted each with check-valves and blow-off, and are also arranged to supply a fire-hydrant at the same place. This fire-hydrant, being placed in a commanding position at the top of the embankment, is designed to provide more particularly against exterior fire, and the removal of a few stop-plank at the reservoir will give it many hours' supply, with a head of 124 feet.

From the engine-house to South street a roadway 40 feet wide is constructed to provide access to the works. The main is laid

for about half its length under this way, the deflection eastward of the street to avoid the rise of the hill, rendering unadvisable its being laid thereon, as it required an increase of length and is detrimental to the alignement. As the heavy teaming, coals and supplies of all kinds, will pass over this street, it has been well drained and Macadamized, and opens a right of way to many valuable building sites on the northerly slope of Walnut Hill. The force-main delivers the water at the middle of the easterly embankment of the reservoir into the influent-chamber.

RESERVOIR.

The Reservoir is on Walnut Hill, in Medford, near Tufts' College. It is both receiving and distributing, — its nearness to the city rendering unnecessary any other for keeping up the supply at all times. Its location is peculiarly favorable, as it lies in a direct line between the lake and Charlestown, and is the only eminence of sufficient height, within a circuit of several miles, admitting of obtaining the desired head; its position and height in fact rendering it the most desirable site for supplying any of the towns lying between the Charles and the northerly slope of the Mystic River. It has been constructed with much care; the natural soil, clay with an admixture of sand in just the proper proportions, being one of the best known for the construction of earthen embankments calculated to hold water. Its water surface covers an area of 4½ acres, being in shape nearly a parallelogram with a length of about 560 feet, and a width of 350 feet. It is divided into two portions, nearly equal in area and content, by a partition wall, the top of which is five feet below high-water line, so that when filled, or not drawn down five feet, the reservoir has the appearance of one large basin. It is 25 feet in depth, the top line of bank being three feet above high-water mark. At this level the capacity is 26,244,415 U. S. standard gallons; below the level of the partition wall the united capacity of the two divisions is about 19,000,000 gallons. The embankments were made with great care, the excavated material carefully compacted, being placed in the

work in layers of some six inches wetted and rolled with grooved-rollers, and compressed by the teams; they are believed to be impervious to the passage of water. The footings where the old soil and new meet are stepped, so that a continuous surface line is everywhere avoided. The slopes inside are lined with a puddled walling two feet thick, which is covered with a facing of eight inches of brickwork up to a line 4½ feet from the top, where the lining is faced and coped with cut granite masonry. This last is laid in three courses of eighteen inches each, with projecting coping two feet wide. The inside of the top of the brickwork has a slope of one and one half feet horizontal to one vertical, the granite masonry having a slope of three inches to one foot. The exterior slopes are one and one half to one, and are intended to be soiled and sodded. The partition wall has slopes of one to one, faced and covered with brickwork, and backed with puddled walls two feet thick. The division of the reservoir into two parts is designed to promote subsidence, and facilitate repairs and cleansing. The top water line is 147 feet, and the bottom 124 feet above high-water level of the harbor, and is so arranged that the water is always drawn four feet from the bottom, this lower basin serving as a depositing area for much of the impurities that would otherwise be carried into the city pipes and there be distributed. The bottom of the reservoir is puddled and covered with concrete three inches thick. The footing and base of the brickwork has a foundation and backing also of concrete masonry. The embankments are 19½ feet wide on top, and are laid out with a gravel walk eight feet wide. A handsome roadway about forty feet wide passes around three sides of the reservoir, at the foot of the embankment, and materially improves the appearance of the whole work. The grounds on the westerly and southerly sides are too limited, those on the easterly being ample, and when laid out will tend to render attractive a locality that will sooner or later become a place of resort.

The appurtenances of the reservoir are the influent, effluent, and drain chambers, the delivery and drain pipes.

INFLUENT CHAMBER.

The Influent Chamber is located within the easterly embankment opposite the partition wall, and, as its name denotes, receives the water from the force-main. It is constructed of hydraulic brick masonry with cut granite coping, sills, and covering. It is arranged so that the supply is fed to each reservoir separately, by means of circular brick galleries 2½ feet in diameter, and which enter at the angles made by the partition wall with the eastern slope. These corners are made into flat water-ways reaching to the bottom, and protected from wash with coverings of North River flagging stone. The flow into the brick gallery is regulated by stop-gates, and can be cut off from both so as to pass directly through a 30-inch pipe to the effluent chamber. This pipe is of iron and cement, and is partially laid through a portion of the easterly and southerly embankments, entering at the effluent chamber a small well made to receive it.

The 30-inch delivery pipes, of iron and cement, are laid upon the bottom of the reservoir and covered with hydraulic cement mortar. They are so arranged that the water can be drawn to the effluent chamber from either or both divisions of the reservoir, or cut off from both.

The drain-pipes of 12 inches, of the same material, are similarly arranged, but convey the water in an opposite direction to South Street. They are regulated by stop-gates enclosed in a chamber of brick and stone masonry, on the northerly side of the reservoir. The drain-pipes are laid under the bottom, which in each division has a fall of six inches to the drain inlets.

EFFLUENT CHAMBER.

The Effluent Chamber is situated on the exterior slope of the southerly embankment, and is of hydraulic brick and cut granite masonry. It is one of the most substantial structures upon the works; the top of foundations start on a level with the bottom of the reservoir. It is in three divisions called the receiving, the well, and delivery-gate chamber.

The receiving gate-chamber contains the 30-inch stop-gates, which regulate the flow from the delivery pipe to the well-chamber. These gates are quite massive and will be operated with proper gearing from the upper floor.

The well and screen chambers form the middle division of the building, and can be divided into three parts, by means of stop plank, so that any one portion can be repaired or cleaned without affecting the supply of water to the city. The well is designed to contain double sets of copper screens for each part, though at present but one division is used. The water in the well stands at the same level as in the reservoir, and, after passing the screens, enters the 24-inch pipe in the delivery gate-chamber.

This chamber is designed for three lines of pipes, though but one is now laid. The 24-inch gates here regulate the flow of water to the city, and will be operated in the same manner as the 30-inch gates. The flooring of the building is designed to be of iron and glass, but at present is not completed. Over the chamber a handsome gate-house has been erected, constructed of face brick and sandstone. From its position, it forms a prominent feature in the landscape, and from the observatory on top, a fine view of the surrounding country is obtained. The masonry of the reservoir was performed under the superintendence of Henry Dana, of Charlestown; it is considered one of the best works of the kind in this country.

SUPPLY MAIN.

The supply main from the reservoir to the Neck, in Charlestown, is of cast iron, 24 inches in diameter, and delivers the water to the distributing pipes in Charlestown and Somerville. This main passes under the Boston and Lowell and over the Boston and Maine Grand Junction and Eastern Railroads. It is 16,250 feet in length, and holds 383,000 gallons, and will deliver at the Neck, when the reservoir is filled to high-water mark, 10,000,000 U. S. gallons in 24 hours.

Two favorable opportunities occur for wasting the water from the

main, — one at Medford Street in Medford, the other on Broadway, in Somerville. These wastes are fitted with all the essential stop-gates, and pipes, and drain into the natural water-courses. A second gate of 24 inches admits of the water being shut off near the Somerville blow-off.

Some few leaks, mainly owing to defective pipe, have been discovered, and, with one exception, repaired before the water was delivered to our citizens. This occurred in a quicksand cut near the convent grounds in Somerville, and, owing to the severity of the weather, and the difficulty of excavating the treacherous quicksands with so much water present, the work has been left until a warmer and dryer season. The flow from the leak is not great, and with ordinary care no damage need ensue therefrom. The main with all its appurtenances appears to have been well laid, and is daily giving evidence of its fitness for the work designed for it. With but one line of pipe, it is desirable that as few connections should be made with it as possible, as every such increases the liability to accident, which would occasion the water to be shut off from the city.

Wherever the line of aqueduct passes through the streets of Medford or Somerville, the act of the Legislature requires that hydrants shall be placed at distances not exceeding 500 feet apart. This has required the placing of 17 fire hydrants, 14 of which are connected with the main pipe, the remainder at present laid being on the 8-inch pipe, which runs parallel with the mains through a part of Broadway. Stop-gates are placed in every hydrant pipe, so that in case of leaky valves they can be shut off from the main. No water supply to a city can be considered entirely safe with but one line of supply mains, and as soon therefore as expedient a second main should be laid. Boston now has three distinct lines. Where practicable, it is generally advisable to vary the route; for where two lines of pipes are laid together, it is difficult, in fact almost impossible, to ascertain, without shutting off the water, in which line it occurs. Whenever a second line of pipe is laid, I would advise its being placed through private lands, as distant from the present line as the right of way will permit, and in highways upon the opposite side of the street.

CITY DISTRIBUTION.

The City of Charlestown, in proportion to its area, has a greater length of streets, ways and courts, than any city in this region. Already well populated and increasing rapidly, it was deemed advisable to lay the distributing pipes through every street and public way that could not in some equally convenient manner be supplied with water. Hence the distribution is very general and the policy pursued it is believed, will, by affording water to a greater number of consumers, very much sooner produce an income from the works sufficient to meet the annual interest and cost of maintenance.

A glance at the map of the city will show that the principal region to be supplied is in shape something like an isosceles triangle, with Chelsea Street as a base, Main and Medford Streets forming the sides. Bunker Hill Street bisects this triangle, while transversely Pearl with Salem, and Lexington with Winthrop, connect the three lines. The principal mains passing through these streets make a complete water circuit, while lines through Chapman, Washington, and Bow Streets provide for the region south-west of Main Street, and complete a circuit through that locality. From these principal mains the submains of 6 and 4 inches diameter pass through the various streets, connecting at all points wherever the lines cross each other. Should at any future time Chelsea and East Boston be supplied, the plan contemplates a 20-inch pipe through Medford to Chelsea Street connecting with the 20-inch pipe now laid therein. This again connecting with the Main Street pipe at the City Square will make a water circuit in the city ample in size for all future demands.

The pipes used in the city, are 16, 10, 8, 6 and 4 inches in diameter. In some of the less important streets and courts, where the demand will never be large, a small amount of 2-inch pipe is laid. The 16-inch pipe in Main Street is designed to connect with the 20-inch Boston pipe, so that, in case of accident to the works in either city, a partial supply could be obtained. The de-

sign as practically carried out has been to obtain the largest possible supply at any one point, and the frequency of connections over so small an area has admitted of this, while a very small amount of pipe, as compared with the population supplied, has been required. Of the various sizes there has been laid in Charlestown and Somerville : —

16-inch, ...	5,206.3 feet.
10 "	3,182.3 "
8 "	20,871.0 "
6 "	34,215.6 "
4 "	33,203.3 "

Of this quantity 4,564.1 feet of 8-inch, and 81.1 feet of 4-inch pipe were laid in Somerville; and 2,392.4 feet of 6-inch, and 682.4 feet of 4-inch at the McLean Asylum.

The kind of pipe that should be laid for distribution was a subject of careful consideration and investigation. That which was adopted is known as the wrought iron and cement pipe, manufactured by the Jersey City Water and Gas Pipe Company. At the time when the works were being designed, although many miles of this pipe had been laid in other places, yet in none had it been adopted as a system for a whole city or town. In fact, it had been mostly in country localities where the number of connections were small, and where the streets were not filled with obstructions of sewers, drains, and gas-pipes, and many of its advocates doubted its reliability for city service. With but three months of use, it is not possible to rely upon *our experience*, and, as the adoption of this pipe is by a very large number of our citizens still considered a novelty and experiment, it is but just that some of the many reasons that led to its use should be given. I therefore append extracts from my previous reports on the subject. (*Vide* Appendix A.) All of the work pertaining to the manufacture and laying of this pipe, as well as the setting of all stop-gates and hydrants, in fact everything to place the pipe in readiness to receive the water, was performed by the Pipe Company, under the superintendence of Mr. Johnson Davie, and it is proper to say that their contracts have

been faithfully and conscientiously performed, as the very small number of leaks in the pipes below 16 inches evince. The whole number of leaks in 16½ miles of pipes, was seven. In the 16-inch main, owing to imperfect workmanship in laying, trouble was had with the joints; but at present the pipe appears to be entirely tight.

The contract with the company guarantees this 16-inch pipe for two years, and should it not in every respect answer all the purposes of a water conductor as well as iron, it is to be laid with cast-iron pipe at the expense of the contractors.

STOP-GATES AND HYDRANTS.

Next in importance to the pipes themselves is the means of regulating the flow of the water through them. To the construction and placing of the stop-gates, great attention has been paid, so that economy in maintenance may be obtained and subsequent alterations avoided. In the city proper there has been laid 269 gates of 4 inches and upward, 89 of which are in connection with the Lowry hydrants, and 180 are of the Coffin pattern. Upon the mains and distributing pipes within and without the city, there are 289 gates, giving an average of over thirteen gates per mile. By comparison with other cities when their works were finished, can we best judge of the completeness of our own system: —

Boston,	1848	60	miles	pipage	532	S. G.	9	per mile.
"	1852	100	"	"	897	"	9	" "
Jersey City,	1854	20.4	"	"	121	"	6	" "
Brooklyn,	1858	120	"	"	690	"	5.8	" "
Louisville,	1861	25	"	"	191	"	4	" "

The stop-gates are all boxed and fitted with heavy street covers, and are large enough for the entrance of men for repairs or oiling.

The fire hydrants adopted for the city are of the kind known as the "Lowry Hydrant," and differ in very many respects from those generally used in other cities. They are 10 inches in diameter, and are placed directly on the mains and generally at the inter-

section with cross pipes. By this means the greatest possible volume of water is secured, the flow being equivalent to all the pipes connected with the hydrant. By this arrangement also, is combined with the hydrant one or more stop-gates as may be required for shutting off, if desired, the water in the mains. Each of these hydrants is so arranged that they supply six hand-engines or four steamers. There are placed in the city 97 of these, which are equivalent to 582 common hydrants. There are also within the city 4 hydrants of the common pattern. Without the city 25 of the same style are connected with the works. In addition to the supply from our own works, there are 11 hydrants connected with the Boston pipes. I think it safe to assume that the city is well supplied with the means of extinguishing fires. As soon as practicable the old reservoirs should be connected with the water supply, as in case of accident to the main line they could then be resorted to. It is but just that the reasons assigned for adopting so radical a change in the hydrant system should be given, and I append extracts from my reports recommending the same. (*Vide* Appendix B.) The stop-gates and hydrants were constructed by Messrs. A. Sylvester & Co., and were submitted to the most rigid tests before acceptance.

SERVICE PIPES.

The pipes from the mains to supply the consumers are generally of lead, of sizes from ½ to 2 inches diameter. They are laid from the mains to two feet beyond the line of the street at the expense of the city. This course, while it creates a considerable increased expenditure at the outset, induces a more general taking of the water, and consequent increase of income. To avoid digging down or disturbing the main pipe, a stop-cock is inserted in the service-pipe, for letting on or shutting off the water, just within the line of the curb-stone. These are all fitted with wastes, so that in shutting off, the house pipes are completely drained. The services have been laid by Mr. Alexander Campbell, and in no instance has a leak been discovered at the junctions with the main pipes, — the point at which the most difficulty was apprehended.

METERS.

Wherever the consumption of water is large, the measurement by metre cannot be too strongly recommended, and their gradual introduction is advisable. Until such time as the action of our water upon the "iron meter" is fully known, I cannot advise large purchases, as the experience of Boston with nearly similar water is not at all satisfactory. The present number on hand and placed in the works is fourteen.

Of the many sources of waste, there are two to which I would at this early day respectfully call the attention of the Board, namely, hopper water-closets and yard hydrants. The first should not be allowed without waste-preventers. The use of the last should not be allowed at all.

The constant liability of house-fixtures to get out of order is noticeable, and in this connection I would urge upon the Board that they require the use, by consumers, of *compression* cocks. These wear longer without dripping, and prevent the water-hammer, which is liable to strain the pipes and produce leaks. Urinals should have self-acting valves.

It may seem premature and unnecessary, so early in the history of our works, to allude to the subject of waste, since, as I have shown, our works are so ample in capacity; yet, when it is impossible to take up the report of any other Water Works, especially those of long standing, without finding repeated allusions to the recklessness which seems to pervade their communities in regard to the consumption of water, we cannot but feel that our citizens should bear in mind that, ample though our work may be, still each drop of water has a money value. It does not flow from the ample source to its elevated site on Walnut Hill of its own accord, but must be pumped there at a cost, an annual cost, that must continue for all time, and for which all are directly or indirectly taxed, so that any one saving in consumption, is a saving to all our citizens.

FOUNTAIN.

But one public Fountain has as yet been constructed. This is located in the centre of Winthrop Square, and forms an attractive

improvement to that locality. At present it consists of a circular basin with a plain cut-granite curbing 37 feet in diameter, and is furnished with the necessary fittings for receiving different jet-pieces. These are so made as to fit the various Boston patterns, and, upon the occasion of our recent celebration, their various forms were kindly loaned us for use. Owing to the frictional resistance of the small pipes leading to the fountain, the jet is not so high as many anticipated, yet the 10-inch stream rose to a height of more than 80 feet; and, with a full reservoir, will reach 90 or more.

With so few public squares, it is not probable that many fountains will be erected by the city, and I trust the liberality of our citizens will be shown, ere long, by placing in the centre of the Winthrop Square basin an appropriate fountain.

The work was constructed by Mr. Robert Wiley, is most substantially done; and the utmost care has been taken to provide foundations that will last forever.

ENGINEERS AND CONTRACTORS.

For convenience and to insure a proper supervision of construction, the engineering work was divided into three portions, under the direction of David W. Cunningham, Esq., as principal assistant. The northerly division, embracing the lake, dam, and conduit, was in charge of Mr. Charles E. Fogg, as resident engineer. The southerly division included the engine-house, iron pipes and reservoir, and was in charge of Mr. M. G. Grant, while the city distribution was in charge of Warren Stetson and Charles H. Swan. To all of these gentlemen and their assistants I would express my thanks for the skill and fidelity with which they performed their varied duties, and for their hearty coöperation in carrying out my plans, by which the successful completion of the work has been much promoted.

The contracts for the greater part of the work were awarded in 1862, after a careful examination as to the skill and reliability of the several parties.

They were as follows: —

Dam, Conduit, Reservoir, Iron pipe laying,	James McDonald, of Albany.
Iron pipes and castings,	Warren Foundery, New Jersey.
Iron and cement pipes, Laying ditto,	Patent Water and Gas Pipe Company, New Jersey.
Hydrants and stop-cocks,	A. Sylvester & Co., Boston.
Pumping-engines,	H. R. Worthington, New York.
Engine-house,	W. W. Bray and J. B. Wilson, Charlestown.

To Mr. McDonald was awarded the largest amount of work given to any one contractor. In a contract in which labor was so large an element, based upon prices extant in 1862, it is not strange that early in 1863 it became evident, from the great rise in price of everything entering into his contract, that not only was he likely to be deprived of the reasonable and ordinary profit upon his undertaking, but was liable to become a heavy loser should he continue the work. With a perseverance and skill most heartily to be commended, when partially relieved by the Commissioners, he continued to freely give to the work his valuable labor and superintendence. Conduct so honorable and praiseworthy is deserving the thanks of all, and most cheerfully do I accord to him my thanks for the valuable assistance he has, and always was, so willing to render.

It is specially gratifying to accord to all the contractors my thanks for the energetic manner in which they have performed their agreements, and to state that we were fortunate in meeting with men who, in such trying times, have so faithfully performed their engagements.

CHANGES IN THE WORKS.

Since the works were originally designed very many and important changes have from time to time been made; and which,

aside from the difficulties occasioned by the extraordinary financial condition of thc country, have been the means of largely enhancing the cost of the works. Their size has been increased, while the character of the work has been improved, — changes that enhance its value and add to its permanence.

Some of the most important of these changes are the extension of the sheet-piling, concrete foundation and wing walls at the dam; more complete grubbing and clearing; increased size of gate-houses, and more expensive masonry and fittings; increased size of conduit and foundations; extraordinary pumping for low grade of conduit; increase in 36-inch mains; bridge, &c.; engine-house of greater capacity, and more expensive style; lowering Mystic River; increased length of force-main; increased size and height of reservoir, and changes in character of masonry and changes in character and size of gate-houses and appurtenances; extension of and more expensive distribution. Add to these the cost from delays and the enormously enhanced price of all labor and materials, and the increase in the cost of the works is readily accounted for. It is satisfactory, however, to be able to state, that notwithstanding the apparently heavy outlay, the cost of the works per million gallons of capacity, is less than one half of any pumping work yet constructed in this country.

Cities.	Date of Construction of Works.	Cost.	Amount of Pipe in miles.	Capacity of Reservoir.	Population at time of Completion.	Capacity per 24 hours in Gallons.	Cost per head of Population.	Cost per Million Galls.
		DOLLARS.					DOLLS.	DOLLS.
New York . . .	1842	13,000,000		175,000,000	340,000	40,000,000	38.20	300,000
Boston	1848	5,200,000	60.0	136,000,000	135,000	15,000,000	38.50	346,666
Brooklyn	1859	5,000,000	12.0	175,000,000	270,000	30,000,000	18.51	166,666
Jersey City . . .	1855	750,000	20.1	55,000,000	28,000	2,000,000	30.60	375,000
Hartford	1856	385,000	23.8	. . . .	23,000	1,800,000	16.74	213,900
Cambridge . . .	1856	250,000	14.5	1,764,000	22,000	1,500,000	11.36	166,666
Charlestown . .	1864	800,000	24.0	26,000,000	30,000	10,000,000	26.66	80,000

MAINTENANCE.

The works having been constructed with special reference to permanence and economy of maintenance, it is believed that the annual cost of management and repairs need be but small as compared with many works of less size. Until such time as one engine can be more constantly pumping, it must be done at a loss of all fuel used in rebuilding fires, banking, &c. But it is gratifying to know that as the consumption increases, the comparative cost of pumping is on the decrease. At present the city consumption is about 650,000 gallons per day, but during the summer of 1865 the consumption will probably increase to nearly or quite 1,000,000 gallons per day, and it would be well not to base any estimate of cost upon a less quantity.

At the present writing, the works generally are in a satisfactory condition. In the spring there will be some repairs and the unfinished construction should be completed.

SUPPLY OF WATER TO OTHER CITIES.

It will be seen that the Charlestown Water Works consist of a source capable of furnishing 30,000,000 gallons daily ; that that quantity can be brought by gravity to the elevating power ; that with the two engines the present works have a capacity of furnishing 10,000,000 gallons per day ; that the City of Charlestown cannot, within its present territorial limits, have use for more than 5,000,000 gallons daily, and consequently can readily supply some of the neighboring towns and cities. In adopting the only available source of a water-supply for a large tract of country, it was deemed advisable to construct the works on a scale ample for the City of Charlestown, and to meet the probable wants of Chelsea, East Boston and the towns through which the line of aqueduct passes. In the design the future supply of these places has been considered, and the works built with reference thereto. Since the opening of the works, application for the use of the surplus water has been made by the cities of Cambridge and Chelsea, while the

distributing pipes are already laid in portions of Somerville. Should a supply be granted to Cambridge, it will necessitate, in the future, either an increase of the source, or some portion of the other localities now estimated as to be supplied must be otherwise provided for. To increase the supply *at the source*, we have the lower Mystic Lake. By bringing the waters of Spy, Little, and Fresh Ponds down through the depression of the Alwive stream to the pumping engines at the Mystic River, we can obtain an additional supply, probably sufficient to meet the prospective wants of Cambridge.

In conclusion, I beg leave to congratulate the Board upon the accomplishment of the work for which we have so long labored.

Respectfully submitted,

C. L. STEVENSON,

Chief Engineer, C. W. W.

APPENDIX.

A.

Extracts from Report of C. L. STEVENSON, *on Pipe System.*

"THE continued delivery through the pipes, it must be understood, depends upon the material of which they are made. If of iron, unprotected from corrosion, they will in a very few years deliver from twenty to thirty per cent. less water. The use of iron pipes has been, until of late years, almost universal; habit and the facility of manufacture causing its use to be continued in many places, notwithstanding its known defects, and as the public generally, more from habit and custom, seem to think there can be no other proper water-conductor, it may be well to recite them. The principal objections are, — Liability to be destroyed in time by oxidation and tuberculation; the loss of capacity and discoloration of the water from the same cause; the cost of the material and of lead jointing, and difficulty of removal, while its weight involves items of expense for transporting and handling freight, distributing on line of work, and labor in laying. The defects arising from the action of the water in producing oxidation have been so thoroughly investigated by other authorities, that extracts from their reports will fully explain them.

"The attention of the Boston Water Board was early called to the subject, and in a report made in 1852, they say: —

"'But, with regard to the accretions, their growth has been more rapid and important; so much so, that our 36-inch and 30-inch mains have become already, in consequence of the actual diminu-

tion of their areas, and also of the additional friction which has been occasioned, scarcely superior in capacity to these of 34 and 28 inches, having a clean surface; and we have had sufficient experience on the subject to convince us of the impolicy of making use of wrought iron service-pipes at all, or of cast iron ones of less than 4 inches in diameter.'

"M. Vicat, in 1833, by order of the Council of Grenoble, in a report given in the transactions of the French Academy of Sciences thus speaks of the filling up of the large cast iron main of the *Château d'Eau*.

"The formation of numerous tubercles of hydroxide of iron began to show itself, shortly after the water was let on, by a perceptible though slight diminution of the discharge. The development of the accretions, however, as was proved by many accurate measurements, soon increased so much that the supply of the *Château*, which had been, in 1826, about 1,400 litres (about 370 wine gallons) a minute, was gradually reduced, in 1833, to 720 litres (about 190 wine gallons), showing a loss of nearly one-half. Two members of the Commission, Messrs. Guemard and Vicat, engineers-in-chief, being persuaded that the tubercles were formed at the expense of the castings, applied themselves to the discovery of some coating which would be, at the same time, cheap, indestructible, and capable of preventing oxidation. After two years of experiments, they considered it sufficiently proved that hydraulic cement is, of all compositions combining facility of application and cheapness, that which adheres best to the casting, is the most indestructible, and prevents most effectually all oxidation and consequent formation of the tubercles.

"In 1837, the subject attracted the attention of the British Association for the Advancement of Science; and, under its auspices, a very elaborate investigation of the action of air and water, whether fresh or salt, clear or foul, and at various temperatures, upon cast iron, wrought iron and steel, was commenced by Mr.

Robert Mallet. Mr. Mallet commenced in 1838, and continued until the year 1843, a very complete course of experiments on the subject.

"He found that any sort of iron, cast or wrought, corrodes when exposed to the action of water holding air in combination, in one or other or some combination of the following forms; namely, 1. Uniformly, or when the whole surface of the iron is covered uniformly with a coat of rust, requiring to be scraped off, and leaving a smooth red surface after it. 2. Uniformly with plumbago, where the surface, as before uniformly corroded, is found in some places covered with plumbagenous matter, leaving a piebald surface of red and black after it. 3. Locally, or only, rusted in some places, and free from rust in others. 4. Locally pitted, where the surface is left as in the last case; but the metal is found unequally removed to a greater or less depth. 5. Tubercular, when the whole of the rust, which has taken place at every point of the specimen, has been transferred to one or more particular points of its surface, and has there formed large projecting tubercles, leaving the rest bare.

"Fresh water may hold as much combined air (not to speak of carbonic acid) as to act more rapidly than sea water. Carbon, as is known, exists in iron as diffused graphite in a crystalline form, and as combined carbon; the dark gray and softer irons contain more of the former; the lighter and harder irons, more of the latter.

"The rate of corrosion is a decreasing one, at least when the plumbago and rust first formed have been removed.

"When, however, this coating remains untouched, the rate is much more nearly uniform, and is nearly proportional to the time of reaction, in given conditions. In some cases where the coating had been removed, an increment in the rate had taken place. And it is observable that this uniformly took place in those specimens which had the smallest amount of corrosion at their first immersion. Thus there was a tendency to a greater equality in the index of corrosion in all the varieties of iron at the second than the first immersion.

"The size and perhaps the form of iron-casting forms one element of their rate of corrosion in water; because the thinner castings, having cooled much faster and more irregularly than the thicker, are much less homogeneous, and contain veins and patches harder than the rest of their substance: hence the formation of voltaic couples and accelerated corrosion.

"He estimates that from three-tenths to four-tenths of an inch in depth of cast iron one inch thick, and about six-tenths of an inch of wrought iron, will be destroyed in a century in clear water.

"The subsequent experiments throw no new light on the cause and nature of this singular phenomenon. They show, however, that the same effect is produced by the action of fresh water and air; and this is too well corroborated by our own experience.

"The important problem of preventing the corrosive action of the water, by coating the interior surface of the pipe, was a principal object of Mr. Mallet's experiments.

"The various results of Mr. Mallet's experiments are exhibited in a full series of tables, which present to the engineer, as he thinks, 'sufficient data to enable him to predict the term of durability, and allow for the loss by corrosion of iron in all conditions, when entering into his structures.' The last information to which we shall refer on this subject is contained in a paper on 'Tubercles in Iron Pipes, by M. Gaudin, Engineer of Bridges and Roads,' published in the 'Annales des Pontes et Chaussées, for November and December, 1851.' He states that the iron conduit at Cherbourg, constructed between the years 1836 and 1838, of white castings, nearly one and a half miles long, had become everywhere coated with tubercles, which in some places had an elevation of from 1.575 to 1.968 inches; so that the orifice of the pipe, which was, when laid, about seven inches in diameter, had been reduced to less than one-third its original section.

"The consequence of the diminution of the orifice, joined to the enormous loss of head occasioned by the additional friction, had deprived many of the workshops at the end of the conduit

of a supply, prevented the simultaneous playing of the fountains, and made the supply of the grand reservoir impossible, or very feeble.

"The tubercles were very broad at their base, and very strongly adhering to the surface of the pipe ; and could not be removed except by heating the pipe to a red heat, or by a forcible action of an instrument. They were of a greenish-brown color, and testaceous structure, and, on exposure to the air, assumed the color of yellow ochre, — a sure sign of the oxidation of part of the iron which entered into their composition. Their density was almost 3,362. He considered it certain that the iron in the tubercles was to be attributed exclusively to an alteration which had taken place in the pipes themselves, no matter what the casting might be, whether white or gray.

"In reference to the obtaining some remedy for the evil, he observes, that waters most pure and proper for the ordinary necessities of life afford no exemption ; since it appears invariable, that the tubercles are in an especial manner developed by the presence of a very small quantity of sea-salt, which almost all waters contain ; and that chemists and engineers have therefore recommended the forcing of linseed-oil by great pressure into the metal, and also coatings of mortars and hydraulic cements and bituminous coverings.

"Undoubtedly, the most important change which takes place on the inner surface of the pipes, as far as relates to any immediate results, is the production of the accretions. The formation of plumbago, or something like it, in the place of iron which has been absorbed, does not, indeed, protect the metal beneath it ; and the action continues, perhaps, even with a slightly accelerated force."

After a careful examination of the Boston pipes, Professor Horsford says, among other things : —

"There are reasons for believing the slight elevations of surface, observed immediately beneath the accretions, to be due to changes

in the texture of the iron arising from the growth of the accretions, and not to an original irregularity of the casting; and, further, for believing that the accretions are indebted for their iron to the surface upon which they rest, and not at all, or but very slightly, to the water which flows over them.

"I have wrought iron pipes, of 1½ inches calibre, which are coated with accretions interiorly, and which, in twelve months, have been eaten through from within outward by the circulation of cold Cochituate water. I have others, of the same diameter, which, in three months, have been eaten through by the circulation of hot Cochituate water.

"I have another pipe, one inch in diameter, which, in twelve months, was so nearly closed by accretions throughout its entire length, that it was removed because it ceased to serve water.

"The solicitude lies in two directions. In the first place, the accretions diminish the serving capacity. Taking the present average thickness of the incrustation at three-eighths of an inch, the serving capacity of a pipe 36 inches in diameter is reduced by the amount of an area of 42⅝ square inches; which is equal to a cylindrical pipe 7.3 inches in diameter. If we conceive the accretion to go regularly forward, at the rate of 14⅛ square inches per annum, it would become a matter of immediate grave consideration. In the second place, the accretions are formed at the expense of the iron upon which they rest. With their increased thickness will come, at a remote period, diminished strength of the iron."

In his annual report for 1863, the chief-engineer of the Boston Water Works states, that "the filling-up by accretions of the mains to South and East Boston, producing a great loss of head, will, before long, necessitate an additional line of mains to both of these places; and it is hoped that some simple and effectual means of preventing the formation of these accretions, which have so seriously affected our whole system of distribution, will be found before the laying of these mains." Since 1858, the accretions in

the Charles River pipes have so accumulated, that thirty per cent. additional head is required to obtain the same delivery.

The difficulties thus enumerated are generally partially mitigated by increasing the thickness and diameter of the pipe beyond the size really required, and by coatings of bitumen, or hydraulic cement. Experience and experiment have shown this last to be the only means of insuring the desired result; but the expense, when added to that of the casting, renders the cost of the pipe excessive. This brought about the use of wrought iron of sufficient thickness to resist the pressure, and protecting it from corrosion by the use of cement. To resist corrosion and overcome the difficulties of manufacture, cast iron pipes are very many times thicker than the water-pressure would require. The defects of manufacture are in foundery work, air-cells, cold-shuts, blisters, sand-holes, shrinkage cracks, and liability to uneven thickness, so that to meet these risks there is large margin given to the thickness beyond anything necessary for mere strength. In testing iron pipes they are made to stand a pressure of 300 lbs. to the square inch, though in practice they rarely have one hundred. To show the resistance of a good piece of pipe, I give the following from Mr. Kirkwood's report: —

"The tensile strength of a 30-inch pipe cast at the Florence Foundery, New Jersey, and afterwards broken up, was tried at the proving machine of the West Point Foundery, February 14, 1857, and found equal to 22,133 lbs. per square inch. This might be considered an average specimen of the iron used in the American founderies for pipe castings. Specimens taken from pipes cast at the Phœnix Iron Works, Glasgow, Scotland, were sent to the South Boston Foundery, and tried by their proving machine with the following results, —

Piece of 30-inch pipe	22,978 lbs. per square inch.
" " 20 " "	24,222 " " " "
" " 20 " "	19,493 " " " "
" " 12 " "	21,290 " " " "

The want of a complete preventive of the corrosion of iron pipes has brought about the introduction of substances professing to combine indestructibility with the greater economy of construction. Among the prominent candidates for favor in this respect, we may mention the "wrought iron and cement pipe," the "bitumenized pipe," the "banded-wood and cement pipe." Lead, tin, copper, zinc, glass, earthenware, rubber, &c., while possessing certain advantages for small service-pipes, cannot well be adopted for mains; an excessive cost and other difficulties militate against their use on a large scale.

In this country, next to cast iron, the wrought iron and cement pipe has been most generally used; and, after eighteen years of trial, has secured such a reputation as has led to its very general introduction as a reliable, economical, and permanent water-conductor. This kind of pipe, as manufactured and laid by the "Jersey City Water and Gas Pipe Company," is made of rolled wrought iron of any required thickness, formed by machinery, and firmly riveted into pipe of any needed diameter, and of sufficient strength to resist any head of water or pressure to which it may be subjected. It is lined by machinery, with mortar made of *Rosendale hydraulic cement*, and laid in a bed of the same material; the entire outside being perfectly covered with the mortar. The cement soon becomes hard, like stone, and protects the metal from the action of air or water, and consequently prevents either corrosion or incrustations.

The sections of pipe are connected by means of a sleeve over the joints made large enough to allow a filling of mortar between the pipe and the sleeve; the whole being also covered externally with mortar, thereby making the joints stronger even than the rest of the pipe.

The application of the Water and Gas Pipe Company and their favorable terms has led to a very careful investigation of the subject, and the result of the examinations would seem to prove: —

First. It will stand any desired pressure.

Second. It can be laid in our streets with safety.

Third. It costs less when first laid.

Fourth. It costs less for repairs.

Fifth. Oxidation does not occur.

Sixth. It insures greater purity to the water.

Seventh. There is no loss of discharge from diminished bore.

Eighth. Less size of pipe can be laid.

Ninth. It increases rather than diminishes in strength with age.

Tenth. It can be more readily tapped for services.

As regards its withstanding the pressure. — The static pressure for Charlestown will equal a head of 150 feet, and it has already been laid in some places where the head is much more, — in one instance 247 feet, and in five others 200 feet and upward. By regulating the thickness of iron, I can see no reason for limiting its ability to resist strain, unless it be in securing the lap properly.

That it can be laid in our streets with safety. — While the natural soil of our city is in a majority of cases every way desirable for a firm bearing to a line of water-pipes, there are some portions of *made land;* and all of the city streets are more or less obstructed with gas-pipes, sewers, drains, and other impediments, generally found in a city so old as ours. I learn from Mr. Albert Stanwood, Superintendent of the eastern division of the Boston Water-Works, that he has in successful operation a long line of the cement pipe, in a location so much worse, for stability, than any place in Charlestown, that no fears need be had of any more trouble, on made land, than with iron pipes ; and similar testimony is given by Mr. Bailey, of the Jersey City Water Works. A personal examination in another city, of the facility with which the pipes could be laid around, over or under obstructions, satisfactorily answered all doubt of readily avoiding impediments in this city.

The first cost of the pipe laid complete and ready to receive the water is from fifteen to twenty per cent. less than of cast iron.

That it costs less for repairs. — Testimony has been procured, from nine different places, all corroborative of the claim, that, as the pipes became stronger with age, there was a yearly falling off in cost of repairs; and in each instance, when a comparison can be had, the testimony is that the first outlay for repairs does not exceed that for cast iron pipe.

That oxidation does not occur. — Samples of pipes laid for some years have been examined by myself, and the testimony of other engineers has been that at no time has a coating been discovered upon the interior lining of the pipes. As a rule, the older pipes present a somewhat smoother surface than those recently laid, doubtless due to the attrition of the water. Samples of two-inch iron pipes have been shown us by Mr. Stanwood, completely filled up with accretions, as also some larger pipes, presenting a loss in diameter of some one and one half inches.

That it insures greater purity to the water. — The discoloration so common in iron pipes, due to the hydroxide of iron, is of course never observable in this pipe. When first laid, however, the water is liable to be affected in hardness by the absorption of some of the particles of lime in the cement. This effect, I am told, soon passes entirely away.

There is no loss of discharge by diminution in the bore. — It has been shown that the loss of discharge in iron pipes is generally equivalent to a loss of two inches of diameter. Thus a pipe of four inches, in time, is quite as effective as the cast iron of six inches calibre.

That a less size of pipe can be laid is therefore apparent, and in this city with its very frequent connections, pipes of four inches of cement, it is believed, will be quite as effective as cast iron ones of six inches. The percentage of saving by this, it will be seen, is important, and reduces the first cost materially.

It increases rather than diminishes in strength with age. — Assuming always that the work is properly done (and unless properly done no pipe is safe), the cement lining and coating prevents the action of air and precludes the chances of oxidation. The well-known property of cement is continued increase of strength from the lapse of time; and, if once properly laid, these pipes must grow stronger with their age.

It can be more readily tapped for services. — The hole for admitting the water to the service-pipe can be made either when the pipe is, or is not, under pressure, and in either case, from the samples shown me, with greater ease and facility than is possible with iron pipes. The method of attaching a service to the pipe consists, first in detaching a portion of the exterior cement, and laying bare the wrought iron. Upon this the cock regulating the flow to the service is securely soldered. The cock being open, a spirally-grooved pointed drill is inserted, and with ordinary pressure passes through the iron, gradually enlarging the hole, so that no spalling off of the interior cement lining takes place. If the pipe is under pressure, the drill passes through a small brass stuffing-box screwed on to the head of the cock where the connecting coupling is attached. On withdrawing the drill, and before entire removal, the cock is shut, so that no water escapes. This method is quite simple, and, unless the workman is careless in the soldering operation, always successful.

Of the wrought iron and cement pipe, there is, I am informed, some one hundred and fifty miles laid and in successful operation in this country. With the facts that have been presented I would say in conclusion, that in my opinion, with proper workmanship, the iron and cement pipe manufactured and laid by the New Jersey Patent Water and Gas Pipe Company, is a proper and safe conductor for water, under the conditions required by our system of works."

Extract of Report of C. L. Stevenson *on System of Fire Hydrants.*

In devising a system of fire hydrants for Charlestown, a study of those of the older cities demonstrated the inadequacy of the hydrant system of most of them for the purposes to which it was applied.

In adapting the hydrant to fire purposes, for the systems of hand-engines still most generally in vogue, the transition from the house-hydrant to the present plug, used exclusively for fires, has been almost imperceptible; custom having caused a continuance of many things that seem somewhat absurd, looking at the matter without a knowledge of its previous history. Let us examine the result, as exemplified at every fire occurring in the cities of Boston, New York, or Philadelphia, or any other city where the steam fire-engine is used. We find that a fire-plug having a bore from 2½ to 3½ inches in diameter is connected with the street mains by pipes varying from three to four inches bore; this plug having a nozzle from 2 to 2½ inches, which feeds through a taper goose-neck or enlarging pipe, and four or five inch suction-hose. The examples, resulting from a necessity of adapting old and existing arrangements to new requirements, do not certainly seem to offer inducements for a continuance of the system where opportunity is afforded for improvements.

Originally, the hydrant was the general method adopted for supplying consumers, and was placed on the outside and oftentimes against the street-wall of the houses or dwellings. Specimens of this are still common in cities where the works are of a comparatively old date. Convenience for fire purposes, without detriment to domestic supply, soon suggested the removal of the plug to the edge of the sidewalk; and the very general use of house-services, or pipes leading from the main into the dwellings, now causes the hydrant to be restricted almost exclusively to fire purposes. Two

kinds (varying in details) are in most general use ; namely, the "post" and "flush" hydrants. These the accompanying diagrams will better explain than any description.

The sizes most used are 3-inch diameter, 2¼-inch nozzle, connected by 4-inch pipe with the street main. One inch of this 3-inch interior space is taken up by the valve-rod through the centre, reducing the actual water-way to 6 square inches, subject to 12½ square inches of frictional surfaces. To supply steam fire-engines, a taper pipe, enlarging to the size of the suction hose, is used.

It can scarcely fail to strike one, that, since the hydrant has ceased to be used to supply consumers, and is for purposes requiring the largest amount of water from the street main in the shortest time, that a more ingenious system of throttling could scarcely be devised. Oxidation of the 4-inch pipes, when of iron also soon causes them to lose some twenty-five per cent. of the original small water-way.

Hydrants are usually placed from 250 feet to 500 feet apart, as the necessities of the locality require. In a thickly-built city, about 300 feet apart is the average. The post-hydrant, from greater convenience is most generally used ; but, when the sidewalks are narrow, it is a great obstruction : hence the use of the flush-hydrant, as in Boston.

When the post-hydrant is to be used, it is essential that it be placed on the side of the street, or it would obstruct the roadway. But, if the flush system is adopted, where the whole is below the surface the question naturally arises, Why isolate it from the street? or, Why reduce its capacity by carrying it away through small pipes from the main feeder, where the supply is many hundred per cent. greater ?

Custom has doubtless caused the flush-hydrant to be still located on the sidewalk ; but it must, I think, be admitted that it is at a decided loss, without compensating advantages.

The hydrant pipe, running off at right angles to the street main, contains dead water, or water without motion, except when the

hydrant is in use; and we are all only too well aware of the amount of packing and contrivances now required to keep our hydrants from freezing in cold weather, — contrivances sometimes effective, sometimes not; and I am told, that, in New York city, where wooden covers were, after some controversy, adopted, one argument of the wood advocate was the facility it afforded, by setting it on fire, to thaw out the hydrant when frozen. While in this the advocate may have been disposed to be facetious, the liability of the hydrant to freeze is no light matter.

As now located, flush-hydrants require a branch in the main pipe, from ten to thirty feet of branch pipe (which, from motives of economy, is always small in size), and the hydrant bend, each helping to reduce the quantity of water the hydrant can deliver.

While each of these adds materially to the cost, and reduces the efficiency of the hydrant, it is evident, that, by placing the hydrant directly over the main in the street, we avoid all of these arrangements, which are only hurtful in their effects. While the capacity will thus be increased enormously, freezing will be rendered impossible, as the water in the mains is always in motion. In porous soils, the water wasted from the hydrant, to empty it after the valve is closed, percolates away through the earth; but, in retentive soils, it is necessary to lead this water to the street sewer.

With the hydrant on the side of the street, this distance must always equal one-half the width of roadway; but when located on the main, the waste drain cannot exceed a few feet in length.

To obtain most economically the largest supply of water, it is evident the nearer we approach the mains, the more surely will this be effected; and, by locating the flush-hydrant directly upon the mains, we not only gain this advantage, but prevent freezing, and do away with the branch, branch-pipe, and hydrant bend.

The views thus entertained on this subject have been more forcibly impressed upon me by examining an invention of a skilful mechanic, Mr. Lowry, of Pittsburg; which, after some four years' trial, would seem to meet the wants of the case, and obviate the difficulty now experienced.

Mr. Lowry, having completed a steam fire-engine for the city of Pittsburg, found his machine comparatively useless, the small fire-plugs of that city being entirely inadequate to feed it; and, to meet this difficulty, he made use of a hydrant of large diameter, placed directly in communication with the main. By an ingenious arrangement, he combines with the hydrant one or more stop-gates, as may be required, for shutting off, if desired, the water in the mains; thus making a combined stop-cock and hydrant. *Vide* diagrams.

This hydrant is usually placed at the intersection of the lines of water pipes, taking the place of the ordinary branch.

It will thus be seen, that the supply to the hydrant is equal to the full capacity of as many mains as it intersects.

For example, a four-way 6-inch hydrant has to supply it the four 6-inch pipes combined, or an area of 113 square inches. The present hydrants have supply from 12½ inches area.

The hydrant, when not in use, is covered with an ordinary stop-cock cover, flush with the level of the street. When in use, a detachable hose-branch, having four, six, or eight attachments, as may be desired, carried by each engine or hose company, takes the place of the cover; being readily fitted to the hydrant by one or two turns, the thread of the screw being slightly turned off at the end, so that one slips readily into the other. The hose attachments are separate and distinct from each other; so that one or eight engines can be supplied at the same time, and let on or shut off the water without interfering, every opening having a separate slide-gate or cut-off.

An ordinary turnkey, passing through the head of the hose-branch, opens or shuts the hydrant valve which supplies the whole eight attachments. With a supply of water so vastly in excess of the capacity of the hydrant, it is evident that each of these is equivalent to eight ordinary hydrants; and, if we suppose a fire to occur in a given locality, eight of the present hydrants would be required to supply the same quantity of water.

The advantages arising from such an excess of supply from the

mains to the hydrant were so well shown in a trial made in Boston in 1863, that a brief account thereof is pertinent. After an exhibition of the powers of this hydrant at Brooklyn, I requested Mr. Lowry to send one to us as a sample, and if possible, for trial. By the courtesy of the Boston Water Board, and the superintendent of the eastern division of the water works, every facility was afforded for a fair trial of its merits. The hydrant, a four-way 6-inch, was located in Winthrop Place, near Franklin Street, at the intersection of two 6-inch pipes, — a three-way 6-inch branch being taken out to admit of its introduction. The spare end of the hydrant was closed by shutting the gate therein. The delivery was therefore such as could be obtained from eighty-five square inches of pipe area, lessened by such accretion as has taken place in the iron; so that the actual effective area would probably not exceed seventy-five square inches.

To this hydrant four of the most powerful of the steam fire-engines in the city were attached by 4-inch couplings. The indicated pressure on the water-gauge, before starting the engines, was thirty-five pounds. The engines were fired simultaneously, and, at the end of twelve minutes, were throwing nine powerful streams of water, subsequently increased to thirteen. With the nine streams the pressure on the water-gauge was thirty-two pounds, and with the thirteen streams was reduced to thirty pounds; thus, of course, showing an excess of pressure from the main of that amount. This result, so contrary to general expectation, was most satisfactory, in showing the advantage of tapping the mains at their junctions.

Upon this same line of 6-inch pipe were located several hydrants of the usual style. To one of these, one steam fire-engine was attached. When throwing two streams, the effect of exhaustion of the hydrant was noticeable; and the interruption to the stream, as shown by the air-spaces, denoted that the engine was drafting from the main.

For the ordinary hand-engine, it is therefore evident, that, even

with eight attachments, the supply will always exceed the delivery; an advantage so manifest that comment is unnecessary.

If we estimate the increased length of hose required to concentrate these eight at a given point, we find another element of economy, which with other advantages, is well shown in the following tables of results obtained at the trials made in Brooklyn, N. Y. prior to adopting them for use there.

Table A.

Statement of Experiments made May 8, 1860, *with Lowry's patent Hydrant, at the corner of Johnson and Prince Streets, Brooklyn, N. Y.*

Head above tide, 139 feet. Pressure of water on the Main, 64 lbs.	Out of Pipe, nozzle $\frac{7}{8}$-inch diameter.			Out of Butt, $2\frac{1}{2}$ inch diameter.		
	Pressure on Main.	Time for 1,000 gals. through openings to which a meter was attached.	Equal for eight openings to	Pressure on Main.	Time for 1,000 gals. through openings to which a meter was attached.	Equal for eight openings to
Eight openings.	lbs.	m. sec.		lbs.	m. sec.	
300 feet of hose, each	58	7.55	8,000 gals. or 127 hhds.	50	4.40	8,000 gals. or 127 hhds.
250 " " "	55	7.30	"	48	4.30	"
200 " " "				45	4.25	"
150 " " "				41	3.20	"
100 " " "				40	2.50	"
50 " " "				33	2.40	"
One opening.						
300 feet of hose, each	63	7.40	8,000 gals. or 127 hhds.	62	4.00	8,000 gals. or 127 hhds.
250 " " "	62	7.35	"	61	3.35	"
200 " " "	60	7.25	"	59	3.30	"
150 " " "	62	7.10	"	63	2.40	"
100 " " "	63	6.55	"	61	2.45	"
50 " " "	63	6.40	"	62	2.00	"

Dimensions and Descriptions. — Hydrant eight inches in diameter, with eight openings, each $2\frac{1}{2}$ inches in diameter, it being set upon a four-way branch, connecting two 6-inch mains.

Eight Openings. — Areas of mains, 113.09 inches; areas of hydrants, 78.26 inches; areas of openings, 39.20.

One Opening. — Area of mains, 113.09 inches; area of hydrants, 78.26 inches; area of open ings, 4.90 inches.

Table B.

Statement of Experiments made May 10, 1860, *with ordinary Hydrant at the corner of Tillary and Stanton Streets, Brooklyn, N. Y.*

Head above tide, 189 feet. Pressure on main, 64 lbs.	Out of Pipe $\frac{7}{8}$ inch nozzle.			Out of Butt $2\frac{1}{2}$ inch diameter.		
	Pressure on Main.	Time for 1,000 gals. by meter.	Equal to eight openings.	Pressure on Main.	Time for 1,000 gals. by meter.	Equal to eight openings.
One opening through	lbs.	m. sec.		lbs.	m. sec.	
300 feet of hose . .	62	8.05	8,000 gals. or 127 hhds.	61½	4.20	8,000 gals. or 127 hhds.
250 " " . .	62	7.40	"	61½	4.15	"
200 " " . .	62	7.20	"	61½	3.45	"
150 " " . .	63½	7.10	"	61½	2.50	"
100 " " . .	63	7.00	"	59½	2.45	"
50 " " . .	62½	6.55	"	57½	2.25	"

Area of main, 56.54 inches; area of supply to the hydrant, 12.56 inches; area of hydrant opening, 4.90.

Table of the relative quantity of Water delivered and Hose used, as between Lowry's Patent Hydrant, intended to be placed at distances of six hundred feet, and the Hydrants now in use, at the ordinary average distance from each other, to reach fires that may occur within an area of three hundred feet radii.

Lowry's Patent Hydrant, with eight openings, assumed to be located 326 feet, being the extreme distance proposed to set them asunder.

Table C.

Pressure on the Main, 63 lbs.

Hydrant.	Distance.	Diameter Hose.	Diameter Nozzle.	Will deliv. in galls.	In seconds.
1 opening . .	100 feet.	$2\frac{1}{2}$ inch.	$\frac{7}{8}$ inch.	100.00	41.50
1 " . .	326 "	"	"	55.40	"
8 " . .	326 ea., or a total of 2,608 feet.	"	"	443.20	
Average distance, 1 opening,	163 feet.	"	"	78.37	"

Whole opening reduced to 2-inch nozzle, ten feet of hose threw 187 feet horizontal

Discharged 8 streams through 300 feet of hose, 102 feet each horizontal.

Eight Ordinary Hydrants, located from fire at the distance shown in the Table, being a fair average distance from any one point.

Table D.

Pressure on the Main, 63 lbs.

Hydrant.	Distance.	Diameter Hose.	Diameter Nozzle.	Will deliver in galls.	In seconds.
	100 feet.	$2\frac{1}{2}$ inch.	$\frac{7}{8}$ inch.	100.00	42
1 opening. .	41 "	"	"	156.25	"
2 " . .	373 "	"	"	51 78	"
3 " . .	431 "	"	"	48.16	"
4 " . .	438 "	"	"	47.80	"
5 " . .	580 "	"	"	41.52	"
6 " . .	591 "	"	"	41.13	"
7 " . .	691 "	"	"	38.05	"
8 " . .	1,076 "	"	"	30.47	"
	4,221 feet.			455.16	
Average. . .	527.62 feet.	"	"	43.57	"

RECAPITULATION.

Minimum length of hose for eight ordinary hydrants, as ordinarily set, ...	4,221 feet,	delivering	455.16	gallons in	42.00	seconds.
Average length of hose for eight openings, patent hydrant, ...	1,304 "	"	626.96	"	41.50	"
In favor of patent hydrant, ...	2,917 "	"	171 80	"	00.50	"
Maximum length of hose for eight openings, patent hydrant, ...	2,608 "	"	443.20	"	42.00	"
In favor of patent hydrant, ...	1,603 "	"	11.96	"	00.50	"
Single discharge from average length of hose, patent hydrant, ...	163 "	"	78.37	"	41.50	"
Single discharge from average length of hose, ordinary hydrant, ...	527 "	"	43.57	"	42.00	"
In favor of patent hydrant, ...	464 "	"	37.80	"	00.50	"

Note. — These quantities are thrown from $\frac{7}{8}$ nozzle.

As stated by Mr. Rhodes (*vide* letter accompanying), the Lowry hydrant gives eight hundred per cent. more water, with a loss of only four per cent. in time, and delivers a single stream of equal volume with ordinary hydrant, with a gain of three per cent. in time; the saving in hose being sixty-eight per cent.

The combination, when desired, of stop-cocks with this hydrant is a feature possessing very considerable merit; enabling us to shut off shorter sections of the city pipes, in case of accident or for repairs, while the additional cost of these cocks is comparatively slight. In a city so irregularly laid out as Charlestown, it is extremely difficult to economically arrange the system of stop-cocks; and, at best, any arrangement, without a large number of stops, will require several streets to be shut off by any accident occurring in certain lines of pipe.

By means of the additional stops afforded by this hydrant, we should be enabled to reduce greatly the size of districts thus to be shut off; and, in case of accidents in smaller lines of pipe, the principal mains can, by means of these auxiliary gates, be kept running: a manifest advantage, as the experience of other cities will show.

To sum up the advantages possessed by this system of hydrant, we have,—

First. Economy in cost and maintenance.

Second. Simplicity and non-liability to derangement.

Third. The enormous volume of water afforded as desired.

Fourth. The ability to supply one or eight engines independently.

Fifth. The saving in hose, and consequent decrease in friction, equal in Brooklyn trial to eighty-seven per cent. increase of water-delivery.

Sixth. It cannot freeze.

Seventh. Doing away with branches and branch-pipes to sidewalks, and with stop-gate boxes and covers.

In advising the introduction of such a system as presented by

this hydrant, several points are to be considered: the general feeling of entire security against any serious conflagration, and consequent reduction of insurance rates; less amount of pipe-line requiring care; streets not broken up by cross trenches to lay or repair the hydrant-pipe, and avoiding the annoyance of shutting off large districts for repairs, the result of the increased number of stop-gates; the number of street-openings for gates is reduced, and, each hydrant with four gates being in one box under one cover, we have the saving of first cost and the continued maintenance of the four extra gate-boxes and covers.

As stated by Mr. Belknap in his report, in localities or buildings more subject than others to fire, the possession of a detachable hose-branch and a few feet of hose in the hands of a watchman would prevent, in many cases, most serious fires that become such by the delay in reaching by engines, and when reached, the detaching of the hose already on to give place to the engine.

Possessing so many manifest advantages, this hydrant is recommended for Charlestown.

Respectfully submitted,

C. L. STEVENSON,

Chief Engineer C. W. W.

To Edw. Lawrence, Esqr.,

Chairman Water Commissioners, C. W. W.

TABLE OF DISTANCES.

Length of dam	1,560 ft.	
Head gate-house to pipe-chamber (including conduit)	7,493 "	
Pipe-chamber to engine-house pump-well (36 inch mains)	487 "	
Engine-house pump-well to reservoir (30 inch force-main)	3,277 "	
Main around reservoir (30 inch pipe)	310 "	
Reservoir to Charlestown Neck (24 inch main)	16,557 "	
Length of works to Charlestown Neck	29,684 "	=5.62 miles
Neck to Charlestown Square (16-inch main)	5,206 "	

TABLE OF LEVELS.

Referred to High Water of Boston Harbor.

Authorized height of flowage of Mystic upper lake (level of Bacon's dam)	7	feet	above.
Top of Mystic dam	11	"	"
Top of conduit, inside, at head gate-house	1.5	"	"
Bottom " " " "	4.17	"	below.
Top of waste weir	0.6	"	above.
Bottom of conduit inside at pipe-chamber	4.92	"	below.
" 36-inch mains under Mystic river	10.50	"	"
" pump-well	11.00	"	"
Boiler-room floor	6.00	"	above.
Engine " "	10.00	"	"
Bottom of force-main at pump-delivery	16.50	"	"
" reservoir	125.00	"	"
Water-level of reservoir	147.00	"	"
Top of embankments of reservoir	150.00	"	"
Highest point on Bunker Hill Street	100.00	"	"
Monument Square at High Street	55.00	"	"
Dry dock at Navy Yard	5.00	"	"

STATEMENT OF WROUGHT IRON AND CEMENT DISTRIBUTION PIPE LAID IN CHARLESTOWN.

Name of Street.	16 in. len. in ft.	10 in. len. in ft.	8 in. len. in ft.	6 in. len. in ft.	4 in. len. in ft.	Totals.
Adams				760.9		760.9
Albion Court					388 5	388.5
Alford				543.2		543.2
Allen					248.7	248.7
Allston					686.6	686.6
Arrow				358.7	250.5	609.2
Auburn				420.4		420.4
Austin				1,568.2		1.568.2
Bainbridge					203.9	203.9
Baldwin					548.1	548.1
Bartlett				1,676.4		1,676.4
Belmont					15.5	15.5
Bow			725.3	559.5		1,284.8
Bunker Hill			4,627.7	666.0		5,293.7
Cambridge			1.006.0			1,006.0
Chamber				252.5		252.5
Chapman			994.3			994 3
Chelsea				3,305.1		3,305.1
Chestnut			295.8	781.9		1,077.7
City Square	204.5		254.3	364.6		823.4
Common					252.7	252.7
Concord					468.1	468.1
Cook					677.7	677.7
Cordis				572.5		572.5
	204.5		7,607 6	11,343 8	4,522.2	23,678.1

Name of Street.	16 in. len. in ft.	10 in. len. in ft.	8 in. len. in ft.	6 in. len. in ft.	4 in. len. in ft.	Totals.
Brought forward . .	204.5		7,607.6	11,343.8	4,522.2	23,678.1
Corey					747.5	747.5
Cross					445.0	445.0
Decatur					979.0	979.0
Dorrance				1,200.8	30.0	1,230.8
Eden					598.5	598.5
Edgeworth					321.5	321 5
Elm				1,586.9		1,586.9
Essex				770.3	26.7	797.0
Everett					639.8	639.8
Ferrin					1,203.0	1,203.0
Fifth					198.3	198.3
First					288.7	288.7
Fountain Pipe . . .			124.8			124.8
Franklin					356.5	356.5
Front				2,369.6	15.0	2,384.6
Furbush Court . . .					268.5	268.5
Gibbs Court . . .					225.0	225.0
Gray					316.5	316.5
Green					900.2	900.2
Harvard					836.8	836.8
Henley				541.7		541.7
High				1,812.2		1,812.2
Irving Place . . .					383.7	383.7
Jay					549.6	549.6
Joiner					496.4	496.4
Laurel					151 5	151.5
	204.5		7,732.4	19,625.3	14,499.9	42,062.1

Name of Street.	16 in. len. in ft.	10 in. len. in ft.	8 in. len. in ft.	6 in. len. in ft.	4 in. len. in ft.	Totals.
Brought forward . .	204.5		7,732.4	19,625.3	14,499.9	42,062.1
Lawrence				1,141.3		1,141.3
Lexington . . .			1,069.9			1,069.9
Linden					509.1	509.1
Lynde					1,141.5	1,141.5
Lyndboro . . .					357.5	357.5
Main	5,001.8			222.6	532.0	5,756.4
Marion					389.0	389.0
Mason					219.5	219.5
Maudlin					385.2	385.2
Mead . . .					522.6	522.6
Medford		3,182.3	2,422.3		61.9	5,666.7
Middlesex . . .				346.7		346.7
Mill					366.0	366.0
Miller					656.0	656.0
Monument . . .					447.4	447.4
Monument Avenue .					652.0	652.0
Monument Square . .			490.0	881.6	468.1	1,839.7
Moulton . . .				1,071.5		1,071.5
Mount Vernon . .					672.1	672.1
Mount Vernon Avenue .					159.8	159.8
Mystic . . .					708.2	708.2
North Mead . . .					13.7	13.7
Oak					480.9	480.9
Pearl			1,493.1			1,493.1
Phipps . . .				205.0		205.0
Pleasant					607.7	607.7
	5,206.3	3,182.3	13,207.9	23,494.0	23,850.1	68,940.6

Name of Street.	16 in. len. in ft.	10 in. len. in ft.	8 in. len. in ft.	6 in. len. in ft.	4 in. len. in ft.	Totals.
Brought forward . .	5,206 3	3,182.3	13,207.9	23,494.0	23,850.1	68,940.6
Polk					679.9	679.9
Princeton . . .					499.5	499 5
Prospect					691.5	691.5
Putnam . . .					301.7	301.7
Quincy					12.5	12.5
Richmond . . .				1,241.8	5.5	1,247.3
Russell				936.4	666.2	1,602.6
Salem			410.6			410.6
School					657.0	657.0
Second . . .					250.6	250.6
Short					340.7	340.7
Sixth . . .					197.9	197.9
Soley					703.0	703.0
Sumner . . .					400.9	400.9
Sullivan . . .					881.7	881.7
Third . . .					221.6	221.6
Thompson . . .				185.7		185.7
Thorndike . . .					247.6	247.6
Tremont . . .					422.1	422.1
Trenton . . .					463.8	463.8
Tufts					736.0	736.0
Union . . .				1,047.9		1,047.9
Vine . . .			623 5			623.5
Walford . . .					204.0	204.0
Walker				685.8		685.8
Wapping . . .				466.3		466.3
	5,206.3	3,182.3	14,242.0	28,057.9	32,433.8	83,122.3

Name of Street.	16 in. len. in ft.	10 in. len. in ft.	8 in. len. in ft.	6 in. len. in ft.	4 in. len. in ft.	Totals.
Brought forward . .	5,206.3	3,182.3	14,242.0	28,057.9	32,433.8	83,122.3
Warren Street . . .				1,599.2		1,599.2
Warren Avenue . .				270.2		270.2
Washington . . .			1,069.9			1,069.9
Water				1,468.9	6.0	1,474.9
Winthrop . . .			994.9			994.9
Wood				427.0		427.0
	5,206.3	3,182.3	16,306.8	31,823.2	32,439.8	88,958.4

STATEMENT OF WROUGHT IRON AND CEMENT DISTRIBUTION PIPE LAID IN SOMERVILLE AND MEDFORD.

Name of Street.	30 in. len. in ft.	12 in. len. in ft.	8 in. len. in ft.	6 in. len. in ft.	4 in. len. in ft.	Totals.
McLean Asylum . .				2,392.4	682.4	3,074.8
Broadway . .			1,501.3		81.1	1,582.4
Franklin Street .			1,065.0			1,065.0
Pearl			220.0			220.0
Myrtle . . .			977.8			977.8
Washington . . .			800.0			800.0
Reservoir . . .	180	472				
	180	472	4,564.1	2,392.4	763.5	7,720.0

Charlestown	88,958.4
Somerville . . .	7,720.0
Medford	652.0
Total	97,330.4 length in feet = 18 miles, 2,290.4 ft.

SUMMARY OF PIPES, STOP-GATES, AND HYDRANTS, CHARLESTOWN WATER WORKS, February 28, 1865.

Main Pipes.

	Diameter of Pipes in inches.									Aggregate.
	36	30	24	16	12	10	8	6	4	
Iron Pipes	974	3,565	16,557		60			212	210	21,578
Cement "		180		5,206	472	3,182	16,307	31,823	32,440	89,610
Bitumen "									417	417
Stop-gates		2	3	3	2	5	27	106	130	278

Service Pipes.

	Diameter of Pipe in inches.					Aggregate.
No. of Services, 988.	2	1	¾	⅝	½	
Length of Lead Services	17	97	5,616	11,841	13,550	31,122
" " Iron and Cement do.	4,017					4,017
" " Bitumen "	520					520
" " Semi-Elastic "	80	558	51		240	929
" " Iron and Glass "		64				64
No. of Stop-cocks, Corporation	52	6	26	242	554	880
" " " Service		4	24	258	725	1,011
" Lowry Hydrants						97
" Common "						26

Weight of Lead Pipes.

	Diameter in inches.			
	1	¾	⅝	½
	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.
All points on a level with, and above the grade of Monument Square, at High Street	4 12	3 4	2 8	
" " below the grade of Monument Square	6 0	3 8	2 12	2 2

COMPARATIVE TABLE OF REPORTED "DUTY" OF PUMPING-ENGINES OF WATER WORKS, PER POUND OF COAL.

Name of City.	Style of Engine.	Date.	Duty.	Remarks.
Brooklyn . .	Double-acting Beam	1860	601,407	Trial made for acceptance of Engine at Ridgewood.
Brooklyn . . .	Double-acting Beam	1863	511,374	Engine No. 1. } Average of Year.
Brooklyn .	Double-acting Beam	1863	540,383	Engine No. 2. } Average of Year.
Brooklyn . . .	Double-acting Beam	1861	606,613	Engine No. 2, trial test.
Brooklyn . .	Crank . . .	1862	649,577	Prospect Hill Engine, trial test.
Cambridge . .	Worthington . .	1857	672,579	Mean of two experiments.
Hartford . .	Crank . .	1857	616,404	Mean of three experiments.
Jersey City . .	Cornish . . .	1857	628,233	Engine No. 1.
Spring Garden .	Cornish . .	1856	589,053	. . . . .
24th Ward . .	Cornish . . .	1863	397.533	Pumps into Stand-pipe.
Spring Garden .	. . . . . .	1863	365.450	Average of Year.
Louisville . . .	Cornish . . .	1863	340.982	Average of Year.
Charlestown . .	Worthington . .	1865	850,000	Mean of three experiments.
Charlestown . .	Worthington .	1865	826,500	Average of February.
Charlestown . .	Worthington . .	1865	800.000	Average effective duty.

MONTHLY RECORD OF WORTHINGTON ENGINE, NO. 1, CHARLESTOWN WATER WORKS.

Month.	Pumping time.	No. of Strokes.	Gallons raised to Reservoir.	Steam pressure.	Vacuum.	Coal for Pumping.	Pump load per sq. inch.
	h. m.			lbs.		lbs.	lbs.
January	97.20	264,198	19,814.875	45	26	34,000	66,076
February	70.30	196,450	14,723,750	45	26	22,600	..

MATERIALS ON HAND EXCLUSIVE OF TOOLS.

Iron pipes	3	of	36	inches	diameter.
" "	13	"	30	"	"
" "	52	"	24	"	"
" "	1	"	6	"	"
" "	14	"	4	"	"
" sleeves	2	"	36	"	"
" "	8	"	30	"	"
" "	5	"	24	"	"
" "	3	"	16	"	"
" "	10	"	6	"	"
" stop-gates	1	"	24	"	"
" "	4	"	4	"	"
Hydrants	6	"	4	"	"
Hydrant-bends	6	"	6	"	"
Quarter-turns	2	"	4	"	"
Saddle-hubs	2	"	4	"	"
Plugs	2	"	12	"	"
"	2	"	6	"	"
"	3	"	4	"	"
Composition corporation stop-cocks	216	"	$\frac{1}{2}$	"	"
" " "	239	"	$\frac{5}{8}$	"	"
" " "	38	"	$\frac{3}{4}$	"	"
" " "	7	"	1	"	"
" " "	12	"	$1\frac{1}{4}$	"	"
" quarter-turns	26	"	2	"	"
" "	61	"	$\frac{5}{8}$	"	"
" service stop-cocks	8	"	$\frac{3}{8}$	"	"
" " "	238	"	$\frac{1}{2}$	"	"
" " "	359	"	$\frac{5}{8}$	"	"
" " "	25	"	$\frac{3}{4}$	"	"
" " "	8	"	1	"	"
" " "	13	"	$1\frac{1}{4}$	"	"
" " "	4	"	2	"	"
Lead pipe, 65 coils	7,920 lbs. A		$\frac{5}{8}$	"	"
" " 49 "	5,231 " A		$\frac{3}{4}$	"	"
" " 41 "	6,586 " AA		$\frac{1}{2}$	"	"
" " 19 "	2,273 " AA		$\frac{5}{8}$	"	"

Lead pipe, 35 coils	3,809 lbs. AA		¾ inches diameter
" " 9 "	748 " AA		1 " "
" " 13 "	1,336 " AAA		1 " "
" " lot	1,270 "		all sizes.
Bitumen pipe	144 feet		4 inches diameter.
" "	481 "		2 " "
" sleeves		73 of	2 " "
" "		27 "	4 " "
" and cement	150 lbs.		
Block tin	12 "		
Solder	142 "		
Lead in pigs	1,960 "		
Iron pipes cracked	72,000 "		
Cut stone	916 cubic feet.		
Spruce lumber (new)	30,544 feet B. M.		
" " (old)	10,700 " "		
Bricks	3,000		
Bolts, nuts, and hoop iron	860 lbs.		
Rope	102 "		
Belting	32 "		

10 bars	1½ inch	round	iron.
3 "	1 "	"	"
1 "	⅞ "	"	"
5 "	¾ "	"	"
13 "	⅝ "	"	"
10 "	½ "	"	"
1 "	1⅛ "	square	"
2 "	¾ "	"	"
4 "	1½ × ½ "	flat	"

130 service box covers.
226 " boxes.
7 stop-gate boxes.
4 Lowry hydrant boxes.
1 " " base.
7 " " frames.
4 " " flat covers.
3 stop-gate frames and covers.
1 " "
3 Boston hydrant frames and covers.
22 " " rings.
2 kettles.

2 furnaces.
3 ladles.
7 yards burlap.
$3\frac{1}{2}$ bbls. of cement.
1 bbl. of oil.
44 lbs. " tallow.
40 lbs. of cotton waste.
54 " " hemp packing.
6 " " Martin's packing.
3 " " rubber "
2 yards canvas.

TOOLS AT ENGINE-HOUSE.

4 iron bars.
2 chains.
3 stone-cutting hammers.
1 stone-hammer.
5 " drills.
21 " points.
19 " chisels.
3 pipe scrapers.
4 derrick blocks.
1 " drum and fittings.
1 " "
1 funnel.
9 oil cans.
1 blacksmith's drilling machine.
1 " bellows.
2 sulphur kettles.
1 pair pipe calipers.
1 centring cross.
1 lead furnace.
1 " kettle.
1 " ladle.
1 12-inch centrifugal pump and frame-work.
12 picks.
19 shovels.
Lot of shovels and picks (worn out).
27 barrow-handles.
1 differential block and fall.
1 lot of pipe dies from $\frac{1}{4}$ to 2-inch.
2 stocks for ditto.
1 set of pipe taps from $\frac{1}{4}$ to 2-inch.
1 " " tongs " "
14 socket wrenches.
9 open wrenches.
4 screw "
10 drills.
12 cold-chisels.
1 die plate, dies and tap.
2 oil cans.
2 copper fillers.
1 oil tank and drain.
2 coal shovels.
1 set of pokers, hoes, &c.
1 coal barrow.
1 Fairbanks' barrow scales.
12 files.
10 draw bolts, &c.
1 hand bellows.
1 ratchet drill and brace.
2 iron clamps.
1 hand drill.
12 glue brushes.
1 spirit level.
1 portable forge.
2 anvils.
1 clock.
1 table.
6 chairs.
6 reflecting kerosene lamps.
1 desk.

TOOLS AT RESERVOIR.

14 shovels (worn out).
5 iron bars.
7 wheelbarrows.
5 hoes.
12 water-pails.
5 dippers.
13 picks.
1 pair stone shears.
1 chain.
2 pinch bars.
1 axe.
1 saw.
2 hammers.
2 watering-pots.
5 rammers.
6 masons hods.

TOOLS AT CHARLESTOWN SHOP.

8 picks.
6 long horses.
8 shovels.
2 iron bars.
2 earth rammers.
2 riveting hammers.
1 paving "
2 stone "
1 face "
1 pinch bar.
1 cold-chisel
12 drills.
3 soldering furnaces.
2 solder kettles.
1 handsaw.
2 bitt stocks.
2 tool-boxes.
1 hand-cart.
2 chisels.
2 hatchets.
1 screw-driver.
2 coach wrenches.
2 service "
1 small steel pick for service-boxes.
1 bench vise.
1 Fairbanks' scales.
2 pails.
1 water dipper
1 watering-pot.
1 stove and pipe
1 trowel.
2 iron-turns.
4 clamps.

TABLE OF YEARLY RAIN-FALL, BOSTON AND VICINITY, 1818 TO 1865.

Year.	Boston.	Waltham.	Lowell.	Cambridge.	Cochituate.	Worcester.
1818	42.99					
1819	35.48					
1820	44.18					
1821	36.89					
1822	27.20					
1823	47 30					
1824	36.02					
1825	35.34	34.59	28.46			
1826	41.14	37.44	32.49			
1827	48.91	50.65	51.86			
1828	32.41	41.71	37.67			
1829	46.85	42.09	36.94			
1830	42.95	47.00	42.59			
1831	51.61	45.77	51.73			
1832	46.69	47.21	52.90			
1833	37.86	39.11	43.87			
1834	39.60	38.91	31.78			
1835	37.86	39.30	32.42			
1836	40.86	35.10	35.53			
1837	33.52	37.98	30.86			
1838	42.52	40.75	37.52			
1839	41.10	38.80	38.21			
1840	49.16	42.00	38.70			
1841	47.05	41.70	40.38			
1842	39.11	38.24	38.61	40.13		40.25
1843	46.69	40.46	39.47	50.81		51.69
1844	37.54	34.09	35.71	35.98		37.57
1845	46.32	43.04	39.00	47.56		39.66
1846	29.95	26 90	28.03	30 37		37.12
1847	46.93	43 90	46.26	48.22		46.94
1848	40.98	36.23	42 29	43.04		39.53
1849	40.30	40.74	41.90	40.97		38.20
1850	53.98	62.13	51.09	54.07		54.42
1851	44.31	41.00	45.68	41.97	43.97	45.68
1852	47 94					59.00
1853	48.86	45.04	43 92	53.83	55.86	59.65
1854	45.71	41.29	42.08	45.17	43.15	59.51
1855	44.19	40.63	44.89	47.59	34.96	55.05
1856	52.16	42.33	42.49	53.79	40.80	49.76
1857	56.87	44.04	49.38	57.92	63.10	51.89
1858	52.67	37.40	37.73	45.46	48.66	
1859	56.70	48.49	47.51		49.02	
1860	51.46		46.91	46.95	55.44	
1861	50.07		43.32	50.14	46.44	
1862	61.06		44.26	57.21	49.69	
1863	67.72	53.66	52.37	56.42	69.30	
1864	49.30	36.56	40.64	49.10	42.60	

ANALYSES OF MYSTIC POND WATERS.

In January, 1836, the water of Mystic Pond was analyzed by Dr. Jackson, of Boston, who gives it as being purer than any of the pond or river waters in this locality, Spot Pond alone excepted. He pronounced it a water every way suitable for all domestic or manufacturing purposes.

In October, 1859, Dr. A. A. Hayes, Assayer to the State of Massachusetts, made a very careful examination of Mystic Pond waters, to ascertain their fitness for the supply of Charlestown and Chelsea. His valuable report was presented to the City Government in connection with the report of Baldwin and Stevenson; and in a subsequent report he states the action upon lead pipes. The conclusions arrived at by him are thus stated: "Considering the nature of the soil forming the water-shed, and the numerous springs affording a large portion of the water, I entertain no doubt that the proposed works will so change the character of the pond-water as to render it more pure even than at present." . . . . "Fortunately, experience has been gained through the introduction of the Cochituate for supply, under conditions so nearly similar to those which will influence the supply from Mystic Pond, that we can rely on that mainly, while with the best efforts to find objections to the water, my results denote what measure of purity may be expected from this source. My opinion is that the supply from Mystic Pond will be of equal purity and desirableness as that derived from Lake Cochituate in every respect; and that the projected improvement of introducing this water for domestic purposes is every way judicious and economical." In his subsequent report, he states that the action of water upon iron is rapid, but that with lead its effects are, as with the Cochituate, to coat the inside of pipes, so that they form in every way a safe conductor for domestic supply.

In November, 1860, Professor Horsford, of Cambridge, was called upon to examine the waters of the Mystic as also those of

Fresh and Spy Pond, and the tributaries of the upper Mystic. His report, which is very full in detail, was made to the Commissioners of Boston harbor. He states that "the water of Cochituate Lake contains in general the same constituents that are found in Fresh and Spy Ponds, and the tributaries of the upper Mystic," and concludes that "the upper Mystic pond is, throughout its depth an eminently pure and soft water."

In July, 1862, Professor Silliman, of Yale College, instituted a series of analyses even more extended than any previous ones. His report was made to the Water Commissioners of Charlestown, a few months prior to commencing the construction of the works, and his results confirm the previous examinations. The results concerning the action of the waters upon lead are as follows: —

ACTION ON LEAD.

There is no question, respecting the use of water, the importance of which is more generally appreciated than that of its action on lead. The almost universal use of this metal for distributing water in houses, and the well-known poisonous character of the salts produced when it yields to the chemical action of water, render an investigation essential in every case where it is proposed to introduce a new source of supply for a city or even for a single family; since, if former experience has taught us anything definite on this subject, it is that there are causes influencing the action of water on lead which are beyond the reach of a satisfactory answer from any source except *actual trial in each case.* It is indeed true, as a general proposition, that lake and river waters do not usually act on lead to an extent injurious to health, while spring and well waters are far more likely to do so. The general proposition is also true that every natural water, if left long enough in contact with the lead, will acquire *some degree* of contamination, — it may be very slight, and it may be limited to the first contact, a second quantity of water receiving no new contamination. Hence it follows in a large number of important cases that lead may be used with impunity for the distribution of water for do-

mestic use: witness our chief cities, Boston, New York, Philadelphia, all of which, and many others, use leaden distribution pipes with comparative impunity. The medical records do indeed show some alarming cases of lead poisoning in these cities, but so rarely and under such conditions as to warrant the conclusion that they are entirely exceptional.

Two series of experiments were instituted to test this question in the case of your waters: —

In the *first series*, lead alone was exposed to the action of the several samples contained in the closed vessels of glass.

In the *second series*, slips of bright lead (six inches long and one inch wide) were prepared with a spot of *plumber's* solder attached to one side, in order that the electrical relations of the lead might be the same as in actual use, every joint in a lead pipe representing in fact a voltaic couple.

Observations were made on the progress of these experiments at the end of an hour, after twenty-four hours, at the end of ten days, and at the end of a month.

As the first series of experiments showed nothing which was not more decidedly shown by the second series, and inasmuch as the latter represent more accurately than the first the results of actual practice, we will not encumber the report with the rehearsal of the details of the first series.

For comparison the second series embraced the Cochituate water, (Boston), Mill River water (New Haven), the well-water from Charlestown, before named, and distilled water.

The action of distilled water is due to the presence of *salts of nitrous acid* which are always present in ordinary distilled water, and whose presence has given rise to the common assertion that *pure water* dissolves lead very rapidly. This is not true; pure water does not act on lead at all. It is as well to correct this popular error, for which there exists the warrant of affirmative statement in many scientific treatises, leading to erroneous conclusions of considerable importance. The fact is that there is present in

almost all natural waters, rain-water included, a volatile compound of nitrous acid and ammonia, which rises with the first portions of water-vapor in the process of distillation, and is never absent from common distilled water. The action of this nitrous compound on lead is peculiar and deserves a word of explanation, since it is the active agent in many cases of lead corrosion in spring waters. The compound which it forms with lead is immediately decomposed by the carbonic acid dissolved in the water forming carbonate of lead (white lead), which is seen instantly to cloud the water. By this process the nitrous compound is set free again to act on a new portion of lead, and so on continuously as long as any portion of carbonic acid is present (and it is always present to some extent). Hence a very minute quantity of this nitrous compound will in time effect the corrosion, by this continuous and constantly renewed process, of a large amount of lead. This is the reason why many waters act on lead in which a careful chemical analysis detects no adequate cause for such corrosion.

The conclusions which follow from the examinations of the action of the waters of upper Mystic upon lead are:—

First. That the waters of the Abajonna River where they enter Mystic Pond are almost identical, in their action upon lead, with the waters of Lake Cochituate.

Second. That the water drawn from the surface of the pond (No. I.) is greatly superior in this respect to any of the other specimens collected at lower levels, and hence it follows,

Third. That in view of this superiority it is important to increase the thickness of the surface water as much as possible over the impurer waters which now rest below the present superficial stratum.

COMPARATIVE PURITY OF WATERS SUPPLIED OR PROPOSED FOR SUPPLYING VARIOUS CITIES.

	Solid residue per gallon, in grains.
Brooklyn, L. I.	2.48
Hartford	2.62
Mystic Pond, Charlestown (by Silliman), 1862	3.22
Lake Cochituate	3.37
St. Charles River, Quebec	3.37
Mill River, New Haven	4.00
Mystic Pond (Dr. Hayes), 1859	4.08
Gunpowder, Baltimore	4.41
Schuylkill (by Boyé)	4.42
Patroon's Creek, Albany	4.72
Cochituate (by Dr. Jackson), 1845	5.00
Pine River, New Haven	5.60
Supplied to Detroit	5.72
Jones's Falls, Baltimore	5.85
Schuylkill (by Booth and Garrett)	6.10
Spot Pond, twenty-six feet deep (by Prof. Silliman), 1845	6.19
Troy	6.29
Fresh Pond, Cambridge	6.32
Ohio River, Cincinnati	6.73
Ottawa and St. Lawrence, Montreal	7.04
Hudson River, Albany	7.24
Passaic, Jersey City	7.44
Mohawk, Troy	7.88
St. Charles, Quebec	8.10
Burlington Bay, Hamilton	8.44
Lake Ontario, Rochester	10.00
Lake Geneva	10.64
Croton River, New York	10.93
Genesee River, Rochester	11.21
Grand River, Hamilton	12.66
Sluice Pond, Lynn (Jackson)	1.44

CHARLESTOWN WATER RATES.

THE FOLLOWING ANNUAL RATES ARE ESTABLISHED BY THE CITY COUNCIL.

SECTION 20. Every dwelling-house, occupied by one family, $6, and $2 each for every additional family; also, $1 on every $1,000 or fraction of a thousand above $1,000 tax valuation. In addition to the foregoing rates, there shall be charged to each dwelling-house in which a water-closet or bathing tub is used, the sum of $5.

Model houses, so-called, shall be charged, for each tenement having water-fixtures within the same, $3 annually; and $3 in addition for each water-closet or bathing-tub used; for each tenement not having water-fixtures within the same, but taking the water from general fixtures used in common with other tenements, $2 annually.

SECT. 21. The following rates for the use of the water in buildings used and occupied for offices, shall be charged, namely, for each office having water-fixtures within the same, $5 annually; and for each office taking the water from fixtures used in common with other offices, $2 annually. And in addition to these rates, there shall be charged for each pan or self-acting water-closet $3, and for each hopper water-closet, $5 annually.

SECT. 22. Hotels, taverns, and boarding-houses (said boarding-houses being valued for the assessment of taxes over $8,000), not including water for baths, or for uses without the house, shall be charged for each bed for boarders and lodgers within the same, $3.

Provided, that in no case shall any hotel, tavern, or boarding-house, be charged less than if a private dwelling-house.

SECT. 23. For each tenement occupied as a store, warehouse, office, shop, or for purposes not included in any other classification, and not requiring more than an ordinary supply of water, $6 to $25.

For each water-closet, more than one supplied for the above, $5 additional.

And for each urinal, wash-hand basin or sink, more than one, $2.50 additional.

SECT. 24. Private stables, including water for washing carriages, $6.

And for each horse over two, $2.

Livery stables, including water for washing carriages, for each horse, $2.

Omnibus stables, for each horse, $1.50.

Truckmen's stables for each horse, $1.25.

Provided, that in no case shall any stable be charged less than $5.

SECT. 25. The right to attach a hose, of not more than five-eighths of an inch orifice, for washing windows, sprinkling streets or gardens, or for use in stables, in addition to the charge for other uses, not less than $3 ; and use of the same shall be limited to one hour per day.

SECT. 26. Refectories, confectioneries, eating-houses, market and fish stalls, provision shops, refreshment and oyster saloons, according to the quantity of water used, from $8 to $50.

SECT. 27. Public baths, for each tub, $5.

SECT. 28. Every printing-office, according to the number of presses used, not including the supplying of a steam-engine, from $6 to $40.

SECT. 29. Stationary steam-engines, working not over ten hours a day shall be charged by the horse-power, as follows: for each horse-power up to and not exceeding ten, the sum of $10; for each, exceeding ten, and not over fifteen, the sum of $8; for each horse-power over fifteen, the sum of $6.

SECT. 30. Every railroad corporation, for supply of locomotive engines according to the quantity used, as ascertained by metres or otherwise, and also for supply of passenger stations.

SECT. 31. Steamboats shall be charged upon the estimated quantity of water consumed, and at the same rate as charged for manufacturing purposes.

Provided, however, that no water shall be allowed for washing purposes, except by special permission from the Water Board, under a penalty of ten dollars.

SECT. 32. For building purposes, for each cask of lime or cement, seven cents.

SECT. 33. Fountains are only to be supplied with water at the discretion of the Water Board; and shall be charged upon the estimated quantity used each day, for each one hundred gallons daily consumption, $5.

SECT. 34. Bakeries. For the average daily use of flour, for each barrel, the sum of $3 dollars per annum.

Provided, that in no case shall any bakery be charged less than $6.

SECT. 35. All manufacturing and other business, requiring a large quantity of water, shall be charged therefor, for one hundred gallons on the average estimated quantity during the year; the year to be estimated three hundred days, as follows:—

When the quantity used averages five hundred gallons per day, or less, at the rate of six cents per one hundred gallons.

When the quantity averages from five hundred to one thousand gallons per day, at the rate of five and two-third cents per one hundred gallons.

When the quantity averages from one thousand to two thousand gallons per day at the rate of five and one-third cents per one hundred gallons.

When the quantity averages from two thousand to three thousand gallons per day, at the rate of five cents per one hundred gallons.

When the quantity averages from three thousand to four thousand gallons per day, at the rate of four and two-third cents per one hundred gallons.

When the quantity averages from four thousand to five thousand gallons per day at the rate of four and one-third cents per one hundred gallons.

When the quantity averages from five thousand to six thousand gallons per day, at the rate of four cents per one hundred gallons.

When the quantity averages from six thousand to seven thousand gallons per day, at the rate of three and two thirds cents per one hundred gallons.

When the quantity averages from seven thousand to eight thousand gallons per day, at the rate of three and one-third cents per one hundred gallons.

When the quantity averages from eight thousand to ten thousand gallons per day, at the rate of three cents per one hundred gallons.

When the quantity used exceeds ten thousand gallons per day, the price shall be fixed by the Water Board, but in no case at less than two cents per one hundred gallons.

GOVERNMENT

CHARLESTOWN WATER WORKS,

1865.

MYSTIC WATER BOARD.

EDWARD LAWRENCE, *President*,
JAMES DANA,
EVERETT TORREY,
EDWIN F. ADAMS,
HORATIO P. DUNNELS.

Clerk of Board,

WILLIAM W. PEIRCE.

Consulting Engineer,

CHARLES L. STEVENSON.


MAP OF WATER REGION
Adjacent to
CHARLESTOWN & CHELSEA
Showing
ROUTE OF CHARLESTOWN WATER WORKS.
Scale, 4000 ft. to an inch.
C. L. Stevenson
Chief Engineer C.W.W.
Feb. 1865.
Area Drainage Basin of Mystic Upper Lake 31 Sq. Miles.
" " " " " " Lower " 3 " "
" " " " Spot Pond 1½ " "
Line of Aqueduct and Pipe shown thus
Limits of Drainage Areas " "
PROFILE OF AQUEDUCT LINE C.W.W.
Horizontal Scale, 2500 ft. to 1 in. — Vertical Scale, 150 ft. to 1 in.
High Water Boston Harbor
READING
SOUTH READING
BURLINGTON
BURLINGTON CENTRE
NORTH WOBURN
WOBURN
WOBURN CENTER
CUMMINGSVILLE
EAST WOBURN
STONEHAM
GREENWOOD
MELROSE
WINCHESTER
LEXINGTON
LEXINGTON VILLAGE
EAST LEXINGTON
MEDFORD
WEST MEDFORD
EDGEWORTH
MALDEN
MALDEN CENTER
MAPLEWOOD
EAST MALDEN
SOUTH MALDEN
WEST CAMBRIDGE
SOMERVILLE
CAMBRIDGE
WALTHAM
WAVERLY
WATERTOWN
CHELSEA
CHARLESTOWN
EAST BOSTON
BOSTON
Spy Pond
Fresh Pond
Spot Pond
Crystal Lake
Mystic Lake
Horn Pond
Walnut Hill
Gate Chamber
Waste Weir
Ventilator
Engine House
Reservoir
Effluent Chamber
Blow off
Charles River